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DESIGN STUDY
OF AN
ALUMINIUM EXTRUSION AND ANODIZING PLANT *

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List of Abbreviations

av. pr - average price

tpy - tons per year

% - per cent

cm^2 - square centimeter

m^2 - square meter

m^3 - cubic meter

kN - kilo Newton - 10^3N (force)

MN - mega Newton - 10^6N

MJ - Mega Joule - 16^6 Joule

GJ - Giga Joule - 10^9J

bar - 0,1 MN/m^2 (pressure)

mbar - mili bar - 10^{-3}bar

Nm^3 - normal cubic meter (at 20°C and 1bar pressure)

cos φ - phase factor

NK^o - water hardness degree

SUMMARY

This Study aims at rendering guidance to developing countries in their efforts to establish an aluminium processing industry. Considering the large assortment of semi-finished products required for production of finished goods, the quick changes in the necessary product mix and the relatively high prices of these goods, it is not expedient to base such a processing industry upon semi-finished aluminium products to be imported. Considerations in respect of a reliable material supply and of economic nature suggest to base the industry of finished products of a country - if this industry is of an important volume - upon a home production of semi-finished goods.

If, on the other hand, a developing country has recoverable bauxite resources of its own and aluminium reserves producible of the former, it can increase the value of the exported metal (exceeding the demand of the home economy) considerably by selling it in a more processed condition, i.e., as semi-finished products or even finished goods.

Taking into account the minimum capacities that can be set up in a technically expedient way and operated profitably, it is usually advisable to start the producing semi-finished goods by setting up the extrusion plant. The feasibility and recommended variants of this procedure are dealt with herein.

Production of the following is taken into consideration:
- extruded profiles,
- extruded profiles with anodized surface,

- in addition to the former, extruded and drawn products such as rods, tubes, wires.

In the case of the first two products, the proportion of low alloyed materials and materials of average characteristics is predominant, while in the third group of products, the share of materials of average characteristics and highly alloyed ones is important.

As regards raw material supply, the Study deals with the following variants:

- purchased billets serve as initial products,
- billets produced by the manufacturer's own plant serve as initial products,
- the production is based on billets which are both purchased and produced by the manufacturer.

In CHAPTERS ONE to FIVE, determining features of technological procedures and facilities are discussed from the point of view of major technological and auxiliary plants. The advisable size of the plant, the required equipment, staff and other conditions of operation, the amount of capital costs, the feasibilities of establishment, etc., are also discussed in respect of each major technological and auxiliary plant.

CHAPTER ONE, EXTRUSION PLANT

It is recommended to install one press and, when the factory is fully developed, not more than two presses. Unalloyed products make only an insignificant proportion of any assortment, e.g., manufacture of unalloyed coarse wires is not profitable nowadays unless made by cast rolling. The smallest press taken into account is a profile press with a force of 16 MN while the largest one would be a tube and rod press of 32 MN. The output ranges from 4,000 to 13,000 ton a year depending on the equipment and product mix.

CHAPTER TWO, BILLET FOUNDRY

If a smelter equipped with a foundry capable of producing billet supply cannot be found in a relatively close vicinity, a foundry must indispensably be developed with a productive capacity amounting to at least 50 per cent of the extrusion plant's demand. This is due to the fact that by processing the manufacturer's scrap (chips, rejects, extremities of billets) in the factory itself, profitability can be improved, while losses occur if these integral scraps are sold and billets purchased instead. Conditions for foundries for producing billets in a quantity of 4,000, 8,000 and 16,000 tpy are considered. When the foundry is fully developed, production of master alloys, homogenizing and finishing processing of billets made of high strength alloys may also be envisaged.

CHAPTER THREE AND FOUR. ANODIZING. INCREASE OF THE PRODUCTS' DEGREE OF PROCESSING

Anodizing is a method widely used to process extruded profiles. The oxide coating thus produced on the surface of the profiles may be coloured or colourless (of natural aluminium colour); utilization of profiles with coloured surface has kept becoming widespread nowadays. If using a proper technology and being provided with adequate machinery, the smallest profitably operated production capacity of an anodizing plant should be at least 3,000 tpy. Therefore, production stages of 3,000 and 6,000 tpy are considered herein, the latter is composed of two anodizing lines of 3,000 tpy capacity each.

Other feasible operations and equipment increasing the degree of processing and the value of products which may be used by extrusion plants are briefly described.

CHAPTER FIVE. AUXILIARY PLANTS

Major topics treated are: power supply and public utilities, maintenance, supply of raw and auxiliary materials (material handling and storage) and shipping of finished products (packing, storing, etc.). Sewage treatment in the anodizing plant is also discussed.

CHAPTERS SIX and SEVEN describe the general conditions related to the setting up and operation of the factory. Among others, the possibilities of gathering technological knowledge and the importance of preparing the sale of products are discussed. The overall staff requirement is also calculated. Layouts and suitable implementation schedules are given for partially and fully developed plants. Simplified comparative evaluation of the efficiency of investment related to possible project variants until fully development has been attained and preliminary profitability estimates for the operational conditions are also made.

The conclusion is drawn that the preparatory work indispensable for well-founded decisions can be carried out if concrete targets, conditions of material supply and marketing and, in general, local circumstances are elaborated and profoundly known, respectively.

PREFACE

This Study aims at rendering help to investors, experts and technicians, etc., having the intention to begin the development of primary aluminium processing industry by establishing an extrusion plant. Such a decision is mostly arrived at in order to obtain, by processing primary metal produced in the country to semi-finished or even finished products, a profit larger than that which would be attainable when it were sold in unconverted state. However, such a decision can be also taken when the country envisages to meet the home market demand by importing, and processing in local plants, primar aluminium (or, wholly or partly, billets) that can be provided and transported without difficulties, instead of importing semi-finished products being considerably higher priced than the former. The profit surplus would remain in the country in this case.

A considerable percentage of developing countries may experience such a situation. This statement is supported by the fact that forecasts on the growth of aluminium industry indicate a development of these countries at a higher rate than the average [1]. The reality of such a forecast is proved by several factors; first of all, by the incontestable fact that considerable reserves of bauxites and natural energy that have not been exploited as yet are to be found on the territory of developing countries, furthermore, that the latest predictions covering the time period up to 2000 taking into account the difficulties of world economy, too, expect aluminium to experience a high rate development in the future [2, 3]. An excellent survey of aluminium industries in developing countries can be found in a paper prepared by UNIDO [4].

Prior to developing, at a large scale, a country's industry producing semi-finished aluminium goods, it is higly advisable to ponder over the aspects set forth in Section 2 of paper [1].

If financial resources are, in general, scarcely available for investment purposes in a country, it is extremely important to manufacture, in the newly established plant, products entirely marketable and to ensure full exploitation and profitability as soon as possible. To that end, very important requirements must be met:

- the capacity of the smallest plant that can be operated efficiently from both the technical and economic points of view should not unduly exceed the really expectable home market demands,
- since the above condition cannot be complied with entirely, the manufacturer must prepare himself to execute export orders raising more strict quality requirements even in the initial operation period.

Considering the circumstances, there are several arguments which may incite any country to establish, at first, an extrusion plant and not a rolling mill for manufacturing aluminium semi-finished products. Such arguments are:

- the smallest economic capacity, and the investment resources necessary to implement such a project, are ten times lower for an extrusion plant than for a rolling mill, under proper circumstances, an extrusion plant producing about 5,000 ton a year may be profitable while the minimum economic capacity of a cold rolling mill meeting all the present-day requirements is not less than approx. 50,000 tpy;
- the utilization sphere of extruded-drawn products shows a wide variety, one third of all the semi-finished

products can be manufactured using this technology, although not always in the most up-to-date manner, e.g., electrical wires;

- it is in the initial phase of industrial development where the utilization field of extruded-drawn products becomes extended abruptly (building industry, electric power transmission lines, transport and repair industry);
- the growth rate of production of extruded-drawn commodities was, in average, twice that of rolled products in Western Europe during the years 1964 to 1980, 10.2 % and 5.7 %, respectively [5].

At the same time, some circumstances impeding the activity should be also taken into account:

- extruded profiles have continuously had to compete with other materials, first of all, plastics, for the market share; Fig. 1 shows the competition experienced by materials of window and door wing structures in the Federal Republic of Germany [6], note that aluminium has been in a more favourable position in other countries, as regards this specific field [5];
- smaller extrusion plants settled near the areas of utilization can form competition even on the part of aluminium products;
- a relatively elevated number of extrusion plants of lower capacity involves a sensibility to primary metal price changes since such plants purchase metal required for their operation on the free market and changes in metal price are reflected in the price of profiles almost immediately.

Apart from those which, having a standard clientele, have specialized themselves to produce a relatively small number of goods at an uncommonly high level, extrusion plants must be prepared to manufacture several

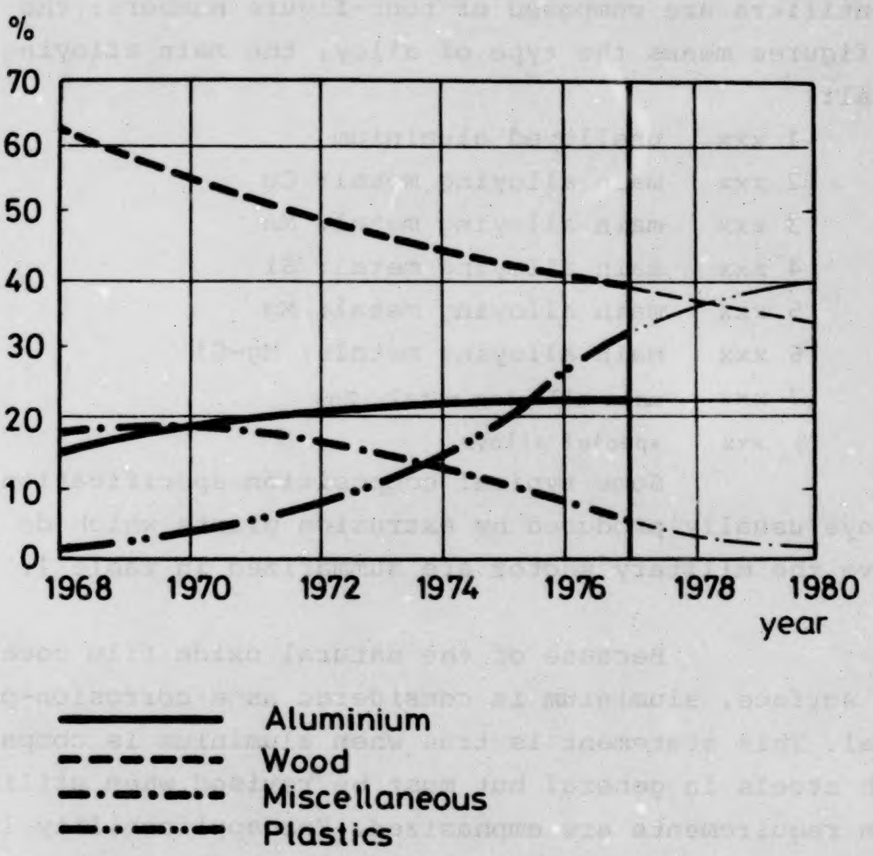

Fig. 1 Materials used to produce windows and doors in the Federal Republic of Germany [6]

types of alloys and their sub-variants; this particularly holds for the initial phase of industrial development of a country.

It is recommended to use alloy identifier according to Aluminium Association (AA) as shown below. Identifiers are composed of four-figure numbers; the first of figures means the type of alloy, the main alloying metal:

1 xxx	unalloyed aluminium
2 xxx	main alloying metal: Cu
3 xxx	main alloying metal: Mn
4 xxx	main alloying metal: Si
5 xxx	main alloying metal: Mg
6 xxx	main alloying metals: Mg-Si
7 xxx	main alloying metal: Zn
8 xxx	special alloys

Some typical composition specifications of alloys usually produced by extrusion plants which do not serve the military sector are summarized in Table 1.

Because of the natural oxide film covering its surface, aluminium is considered as a corrosion-proof metal. This statement is true when aluminium is compared with steels in general but must be revised when utilization requirements are emphasized. For applicability in the building construction industry, the corrosion-proofness of aluminium products should be weighed in the light of two aspects:

- products made of aluminium, such as windows and door wings, facades, hand-railings, etc., should have a service life equal to the expectable life of the building; a radical diminution of reconstruction works should also be aimed at;
- it is atmospherical corrosion, the impairing effect of

Table 1 - Composition of some aluminium alloys for extrusion plants

Alloy identifier according to AA	Mg	Si	Cu	Mn	Fe	Zn	Ni	Ti	Cr	B	Particular specification	Other impurities		Al
												One by one	to-gether	
1050 A	0,05$^{x/}$	0,25	0,05	0,05	0,40	0,07		0,05						min.99,5
1350$^{2x/}$		0,12	0,02		0,35	0,05				0,03	Ti+V+Mn+Cr=0,015	0,02		min.99,5
1200			0,05	0,05		0,10		0,05			Si+Fe=1,00	0,05	0,15	min.99,0
2017 A	0,40-0,80	0,7	3,8-4,8	0,4-0,8	0,7	0,30	0,1	0,1	0,10			0,05	0,15	residual
2024	1,2	0,50	3,8-4,9	0,30	0,50	0,25	0,1	0,15	0,10		Ti+Zr=0,25	0,05	0,15	residual
5056 A	4,5-5,6	0,40	1,10	0,60	0,50	0,20		0,20	0,20		Mn+Cr=(0,10-0,60)	0,05	0,15	residual
5754	2,7-3,6	0,40	0,10	0,50	0,40	0,20		0,15	0,30		Mn+Cr=(0,10-0,60)	0,05	0,15	residual
6005A$^{3x/}$	0,4-0,7	0,50-0,9	0,30	0,50	0,35	0,20		0,10	0,30		Mn+Cr=(0,12-0,50)	0,05	0,15	residual
6063$^{4x/}$	0,45-0,9	0,20-0,6	0,10	0,10	0,35	0,10		0,10				0,05	0,15	residual
6082	0,6-1,2	0,7-1,3	0,10	0,40-1,0	0,50	0,20		0,10				0,05	0,15	residual
6101 B$^{2x/}$	0,35-0,6	0,5-0,6	0,05	0,35	0,10					0,03	Ti+V+Cr+Mn=0,03	0,03	0,10	residual
7020	1,0-1,4	0,35	0,20	0,05-0,50	0,40	4,0-5,0				0,10-0,35	Ti+Zr=(0,08-0,25) Zr=(0,08-0,20)	0,05	0,15	residual
7075	2,1-2,9	0,40	1,2-2,0	0,30	0,50	5,1-6,1		0,20			Ti+Zr=0,25	0,05	0,15	residual

Notes - $^{x/}$ If only one number is indicated, it means the upper list value. 2x/ Material for electrical wires 3x/ Quenchable at press, well anodizable. 4x/ Well-quenchable at press. Well-anodizable.

which must not be neglected; despite all measures intended to reduce its effects, environmental contamination causes considerable damages in cities and industrial plants where such projects are mostly established.

In spite of their diversity, architectural tendencies have had and will have as common objective to construct up-to-date buildings representing also an aesthetical value in addition to being practical.

The requirements of both long service life and decorative appearance cannot be met unless surface treatment is applied. In the United States, for example 95 per cent of all the extruded aluminium products used by the building industry have been surface treated by anodizing for about 15 years and this percentage has shown no signs of changing.

There are several surface treating methods known; it is anodization for protecting extruded products, while various painting processes for rolled ones have come into general use. Painted rolled products will always be deformable to some extent, while brittle oxide layers will not support any deformation. At the same time, it is anodizing that provides the longest service life to aluminium among all the surface treatment methods. Technical-aesthetical value of products intended to be utilized by the building industry can considerably be augmented by coloured oxide layers favourizing also their marketability. Aluminium parts for building industry, if adequately treated, anodized, for instance, and properly installed, require practically no maintenance, do not age off as opposed to plastic materials, and have a highly aesthetical appearance ensuring thus important advantages as comared to other competitive materials in the building industry or in other utilization fields.

The volume of financial resources necessary to project realization can hardly be defined in advance since it depends upon a number of factors, first of all, upon the type of basis plant (rolling mill, extrusion shop), the initial product (purchased billets, pigs), the assortment of manufactured goods (share of profiles, tubes, rods, drawn products, etc.), the extent of processing (e.g. the percentage of products to be anodized), and the price of capital goods. According to paper[1], to establish an industrial aggregation in the full vertical development and an output of 100,000 tpy of finished aluminium products, resources amounting to US $670 million (on 1977 price basis) would be required; 38 per cent of the amount would have to be assigned to manufacturing semi-finished products. Supposing that, in the average, an output rate of 76 per cent can be attained by plants processing semi-finished goods to finished ones and considering the rise in prices of equipment which has taken place in the last years, the calculation will show that, nowadays, an investment of 2,5 million US dollars would be required in order to establish a manufacturing capacity producing 1000 tpy of semi-finished products from pigs (this amount does not include interests and current assets).

The following prices were valid at the end of 1983 (free on bord, packing included, US $/ton):

Al 99,5, pig (LME)	1530
6063, billet	1610-1630
6063, profile of average complexity	2160-2280
idem, anodized, colourless	2350-2550
idem, anodized to bronzine colour	2700-2900

It should be emphasized that the primary costs of the entire plant can be brought down if scrap arising in the shop is properly treated for melting and casting to billets. It is a fact that returning of such scrap into production does not require more energy than 5 per cent of that utilized for manufacturing.

From the point of view of a given plant, the difference between the purchase price of base material and the sale price of shipped products, the so-called phase price, is of primary importance. It can be influenced very favourably by applying anodization, or, generally, by increasing the degree of processing of products to be shipped.

Throughout the present Study, the establishment of an up-to-date plant will be supposed. For, the investor in a developing country, be it a governmental organization or a private company, will be forced to compete with factories of developed countries, as regards both the quality and the primary costs of manufactured goods.

It is to be emphasized that automation of the plants and utilization of computerized control has a great importance not only because of saving in operating staff but also since a uniformly good quality and low, competitive manufacturing costs of the products can thus be ensured. Of course, automation of all the operations and computerized control of the entire process is not necessary even for an up-to-date plant.

The authors have supposed that readers of this Study are familiar with the main technological processes such as extrusion, drawing, billet casting, anodization and so forth. If they are not, it would be expedient to acquire these knowledges by studying text-books and manuals on technology being abundantly available.

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1 - EXTRUSION PLANT

1.1 - Conceptual Description

1.1.1 - General Scheme of Production Process

The manufacturing process in the extrusion plant starts with the receipt of the billets or logs and finishes with packing. If an anodizing is also to be carried out, packing takes place after the same. Provision for dies and packing material, quality control of finished products as well as further processing of extruded products within the factory do not form part of the extrusion as such although part of these operations, or all of them, may be performed in the extrusion shop. The same holds for billet homogenizing if not carried out concurrently with preheating.

Several variants of the manufacturing process can be conceived depending upon the product to be manufactured and the alloys used, on the one hand, and upon the billets available, on the other.

In general, extrusion plants can be classified into two types:

- plants where an overwhelming part of the operations after extrusion - in the most up-to-date shops, all of them - are carried out by a finishing line forming an integrated unit with the press itself;
- plants where a major part of the operations other than extrusion are performed by equipment independent of the press.

For perspicuity, the above types of manufacturing processes in the extrusion shop are outlined in Figures 2 and 3. When describing operations of and equipment required for the manufacturing process, the Figures

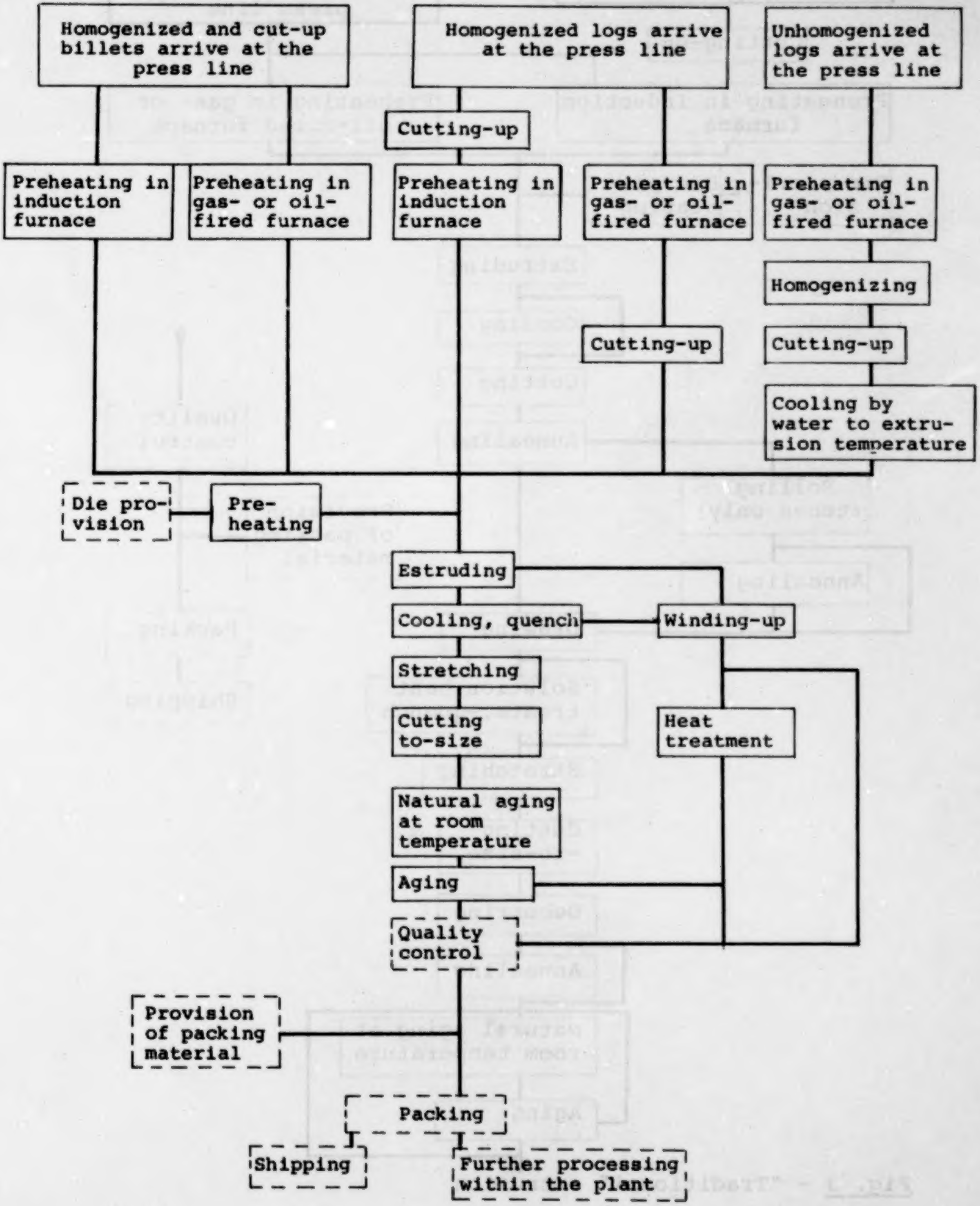
Homogenized and cut-up billets arrive at the press line
Homogenized logs arrive at the press line
Unhomogenized logs arrive at the press line
Cutting-up
Preheating in induction furnace
Preheating in gas- or oil-fired furnace
Preheating in induction furnace
Preheating in gas- or oil-fired furnace
Preheating in gas- or oil-fired furnace
Homogenizing
Cutting-up
Cutting-up
Cooling by water to extrusion temperature
Die provision
Preheating
Estruding
Cooling, quench
Winding-up
Stretching
Cutting to-size
Heat treatment
Natural aging at room temperature
Aging
Quality control
Provision of packing material
Packing
Shipping
Further processing within the plant

Fig. 2 - Extrusion with quenching at the press and finishing on the press line

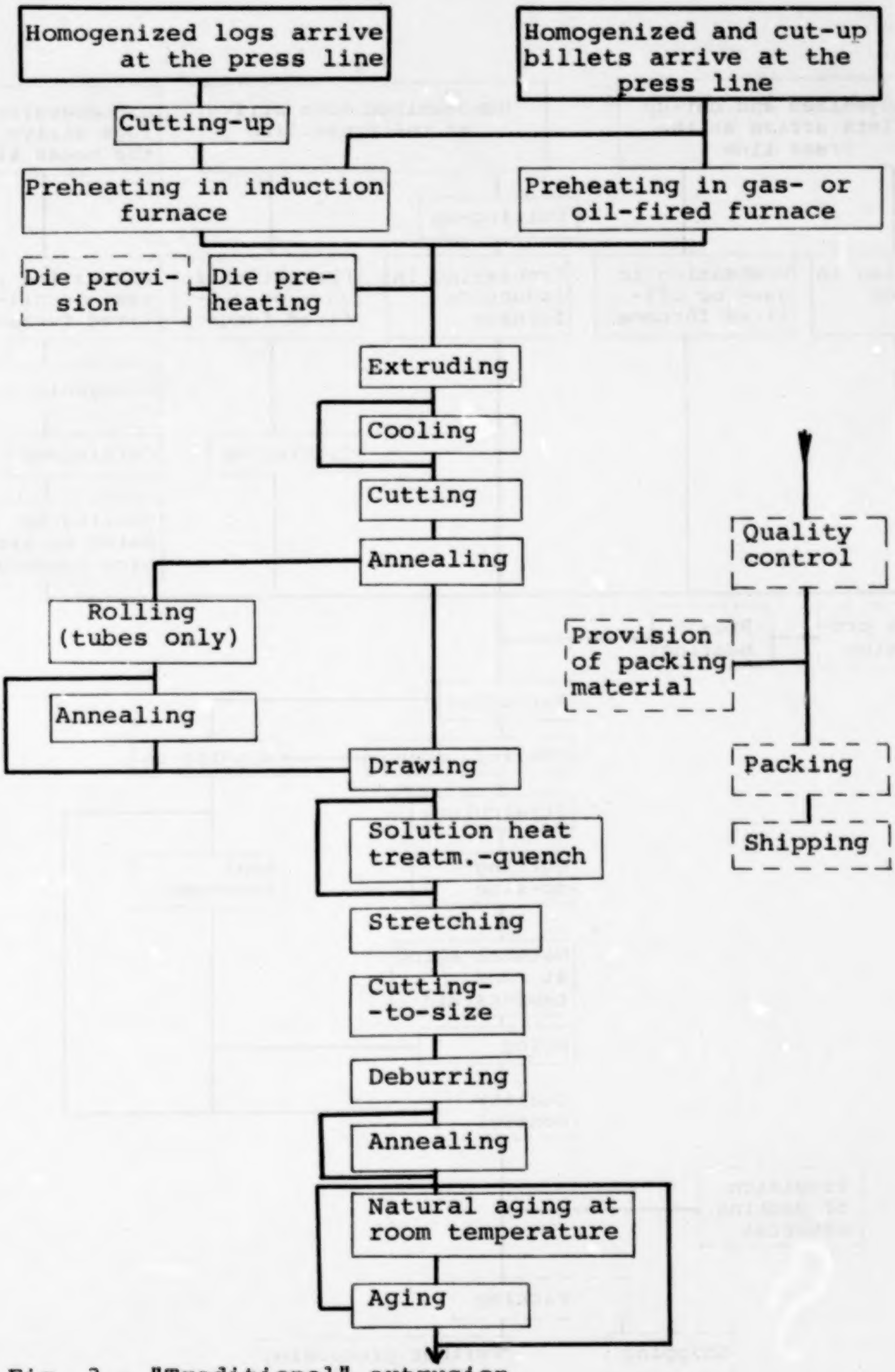
Homogenized logs arrive at the press line
Homogenized and cut-up billets arrive at the press line
Cutting-up
Preheating in induction furnace
Preheating in gas- or oil-fired furnace
Die provision
Die preheating
Extruding
Cooling
Cutting
Annealing
Rolling (tubes only)
Annealing
Drawing
Solution heat treatm.-quench
Stretching
Cutting-to-size
Deburring
Annealing
Natural aging at room temperature
Aging
Quality control
Provision of packing material
Packing
Shipping

Fig. 3 - "Traditional" extrusion

are referred to throughout this Study. (Operations not forming part, in a technically strict sense, of the extrusion are shown in cases formed with dotted lines.)

1.1.2 - Extrusion and Finishing

The product mix of the plant to be described first covers profiles made of low alloyed alloys, first of all, for architectural construction and vehicle industry. As regards size tolerances and surface quality, the profiles have to meet very severe requirements. Recently, for energy and material saving reasons, the proportion of medium alloyed products, featuring higher strength, used to load-bearing structures has been increasing. Similarly, a deviation from the specified mechanical properties within restricted limits only has also been required to be warranted, in order to ensure a forming by the user without difficulties, for instance.

The advantages of plants of this type can be pushed when well-extrudable alloys are to be processed, first of all, heat treatable ones, which attain the desired strength without requiring extremely high cooling rates to be applied, and, therefore, may be quenched at the press.

Plants of the "traditional" type are characterized by products made, in an important proportion, of alloys of high strength. These alloys - if heat treatable - provide the required high strength only when very strict heat treatment parameters and high cooling rates are applied. High strength characteristics of non-hardenable alloys, e.g., those of the Al-Mg alloy group, can be ensured by work hardening. All of these operations are always performed out of the press line. It is to be noted, however, that composition variants permitting an ever increasing number of heat treatable alloys to be hardened at the press have been sought.

First, operations and equipment used in the course of the extrusion process will be described for plant types the operations and the typical arrangement of machinery of which are illustrated in Fig. 2 and 4a, respectively.

For extrusion, the cast billets must be homogenized. Homogenizing is aimed at improvement of hot workability of the material and the properties of the products by solving the non-equilibrium precipitates of main alloying elements forming the hardening phase, equalization of the solid solution concentration, decomposition of the solid solution of additional alloying elements and additives, and transformation of other phases having been formed during casting. High productivity and good quality products cannot be achieved if unhomogenized or insufficiently homogenized billets are used.

For homogenizing, a temperature between the equilibrium solidus and solvus temperatures of the alloy should be chosen. The length of the homogenizing period should be defined in accordance with the time required to the processes described above, on the one hand, and the available furnace capacities, on the other.

Fig.4 Layout of equipment in the extrusion plant

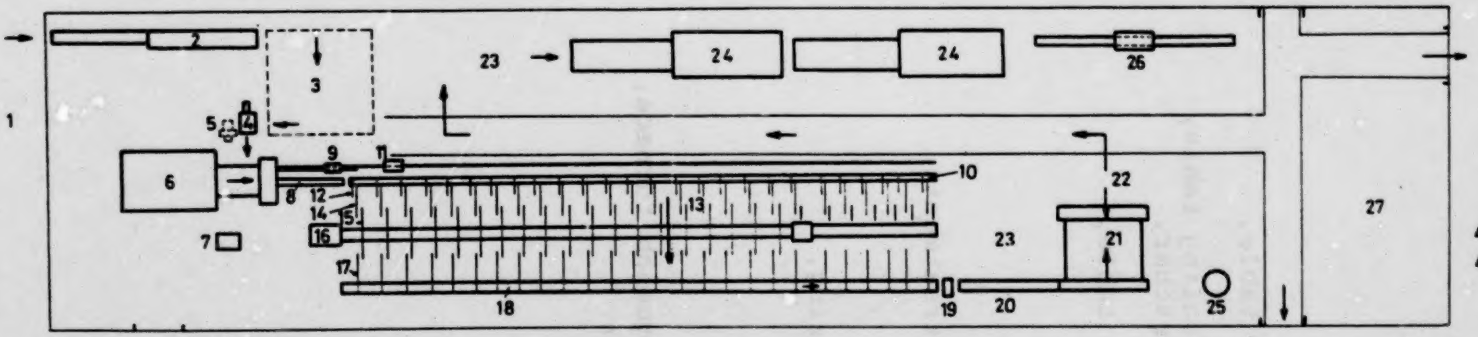
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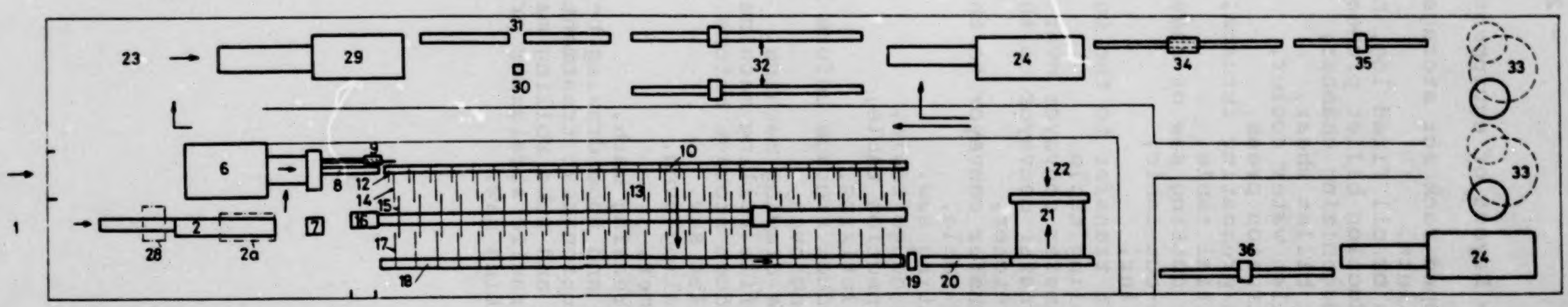
Fig. 4 a Press line and attached facilities for manufacturing profiles of highly extrudable alloys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32
24
34
35
36
33
33
24

Fig. 4 b Tube and rod press line and attached facilities for extruding products of high strength alloys

HALL AREA

4a : 24 x 108 m = 2592 m²

4b : 24 x 138 m = 3312 m²

Fig.4. - Layout of equipment in the extrusion plant

1 - Sloped rack for storage of logs, storage of logs and billets,
2 - gas or oil fired log, billet preheating furnace,
2a - induction billet preheating furnace,
3 - homogenizing chamber,
4 - hot billet shear,
5 - billet water cooler,
6 - extrusion press,
7 - die preheating furnace,
8 - initial table,
9 - hot cutting saw or shear,
10 - run-out table,
11 - puller,
12 - lift transfer to the cooling table,
13 - cooling table,
14 - transfer conveyor over the cooling table,
15 - transfer conveyor to the stretcher,
16 - stretcher,
17 - transfer conveyor to the saw table,
18 - saw table,
19 - cutting saw,
20 - saw gauge table,
21 - inspection table,
22 - palletizing,
23 - product storage before heat treatment,
24 - aging oven,
25 - wire drawing machine,
26 - profile rolling machines,
27 - product storage before anodizing,
28 - billet saw,
29 - anealing oven,
30 - hammer,
31 - degreasing bath,
32 - rod and tube drawing bench,
33 - solution heat treatment and quench furnace,
34 - rod and tube rolling machine,
35 - hydraulic straighner press,
36 - cutting saw.

Temperatures and time periods to be used for homogenizing are summarized in Table 2.

Table 2 - Parameters of homogenizing (for information only)

Alloy	**Temperature, °C**	**Time, h[1/]**
Unalloyed Al [2/]	**600-620**	**4-12**
2017, 2024	**490-510**	**6-12**
5056	**530-550**	**4-8**
5754	**550-570**	**4-8**
6005, 6063	**560-580**	**4-8**
6082	**520-540**	**8-16**
7020	**460-500**	**6-12**
7075	**460-480**	**8-16**

Notes: [1/] **Holding time: for defining the entire cycle time; add the time required for heating up.**

[2/] **Unalloyed metals require homogenizing only if serving for special application.**

Billet homogenizing may be carried out either in the extrusion shop or outside of it, e.g., in the foundry or by the billet manufacturer in chamber furnaces.

After having been homogenized, the billets should be cooled down to room temperature. During cooling, hardening phases form precipitates, the larger, the lower cooling rate is applied. These phases increase the strength of the product if dissolved again; for this purpose, the material should be reheated. This is particularly critical if quenching is made at the press since dissolution of phases requires a certain time that must be the longer the larger the precipitates are and the lower

the temperature is. In order to allow high extrusion speeds to be used, low billet temperatures increasing time needed for dissolution should be provided. Inversely: in order to permit a quick extrusion of billets at appropriately low temperature without risking an unevenly low strength of the product, an even and adequately fast billet coolind should be provided after homogenization so as to obtain precipitated phases of appropriately small size.

Should the billets be cooled at a very high speed, e.g. by using water, precipitation would practically not take place but a high resistance to deformation would occur encumbering the process of extrusion. For low and medium alloyed metals quenched at the press, e.g., 6063, 6005, 6082, 7020, billet cooling after homogenizing is made at a controlled speed in chambers utilizing air, or water spray as cooling media.

Billets have to be preheated for extrusion. For this purpose, induction, gas- or oil-fired conveyor furnaces are used. Cut up billets or logs axially pass through these furnaces following one another. For preheating cut up billets, induction furnaces are recommended but gas- or oil-fired ones are also suitable for the purpose. When homogenized logs have to be preheated in induction furnaces, they must be cold-cut by a saw installed before the furnace. When gas- or oil-fired furnaces are used to preheat the logs, cutting-up is carried out by hot shears immediately before feeding into the press. As compared to colt-cutting by saw, this method has the advantage of producing no chips and cutting up materials of less strength.

In the most up-to-date plants, material is received in the form of unhomogenized logs (see Fig. 4a item 1), the homogenization of which - along with their preheating - forms a part of the operation of extrusion. The logs are preheated, one by one, to the temperature of homogenizing in oil- or gas-fired conveyor furnace (2), then, passed to soaking furnace (3) where they are moved by a conveyor perpendicular to their axis until extrusion takes place. Prior to extrusion, the log is cut up by a hot shear (4) to pieces of the desired length which, after having been cooled by water (5) to the extrusion temperature, are fed into the container of press. As compared to separate homogenizing, the method has the advantage of saving energy required for billet pre-heating; as a disadvantage, difficulties encountered with changes of alloys should be mentioned.

Prior to beginning extruding, the appropriate preheated die should be fitted into the press. (For die provision, see para 1.1.5.)

The main characteristics of a modern press are as follows:

- compact construction, press being suitable to be trial-runned at the manufacturer's shops, requiring a minimum of field mounting;
- highly rigid construction, the main hydraulic cylinder and container being adjusted and guided in such a way that the die, the container and the ram be always coaxial;
- an autonomous oil-hydraulic drive provided by a series of axial or radial pumps of constant or variable delivery, the hydraulic system permitting extrusion to be performed at high, and auxiliary operations at very high rates (motion speed of the main hydraulic cylinder about 20 mm/s and 200 to 400 mm/s, respectively); as a result

of the latter, the dead cycle time to be spent to feed in the billet, to sever the butt discard and dummy block, etc., not exceeding 15 to 20 s;

- quick die change by a unistation die changer permitting all die handling operations from one side of the press, resulting in a time need as short as 20 s, improving the production profitability even for small lots;
- control of the press by means of quickly adjustable programmable control (PC) systems comprising neither relays nor limit switches to be set mechanically, the PC control also serving as an interface to the computer;
- multi-layer containers made of hot fitted shells, heated mostly by induction.

The speed of extrusion largely depends upon the alloy used, the complexity and nature of the product to be extruded, the state of the die, etc., and is therefore variable in a wide range as shown by Table 3.

Table 3 - Extrusion rates to be applied, for information only (m/min.)

Alloy		Alloy	
99,5 Al	50-200	5754	3-15
6063	25-80	2017	2-10
6005	10-40	2024	2-4
7020	5-25	7075	2-4
6082	5-25	5056	2-6

In order to reduce the volume of scrap and the dead cycle time, the presses are equipped with long (40 to 60 m) run-out tables (10). Cooling tables and stretchers are of the same length.

The extrusion, or extrusions, when a die with several holes is being used, leaving the die are moved on the initial table (8) and directed to the run-out table (10), an endless chain mechanism. Cooling fans are placed over and/or under the run-out table. In other types orifices of airducts from high performance fans discharge into the space under the run-out and cooling tables.

To harden not too thick-walled products made of alloy 6063, fan-cooling is sufficient. For products of the same alloy with thicker walls or for higher alloyed materials, e.g., 6005, a higher cooling rate must be provided that can be ensured by utilizing a water spray sprinkler. For certain medium-alloyed materials, e.g., 6082, even water fog does not ensure the required cooling speed. In such a case, the product is passed through a water tank.

For thin profiles extruded through several holes, the use of a puller (11) is indispensable. Having been guided off the press - or cut up, when endless extruding is carried out - the profile extremity or extremities are caught by the clamping fixture of the puller and guided under a preset pulling force along the length of the run-out table at the same speed as extruded. The puller is capable of stopping the press when the extrusion has attained the desired length. The use of a puller is advantageous since it provides for separating the extrusions when a multi-hole extrusion is performed, equalizing for smaller differences in length, improving longitudinal geometry of the extruded product (e.g., twist). When extruding came to an end, the puller runs back to the press.

Extrusions separated from the die will be lifted off the run-out table and transferred to the conveyors (14) forming a cooling table (13) by the walking beam type lift transfer (12). Fans are provided under the conveyors, too.

The cooled down extrusions are taken by another conveyor (15) between the clamping jaws of the hydraulic stretcher (16) and, when stretching is finished, onto the conveyor (17) feeding the saw table.

The jaws of the stretcher are wide enough, 500 mm or more, as to permit several extrusions to be stretched concurrently. Stretching serves for solving residual tensions and for improving geometry of the products, both longitudinal and cross-sectional. The elongation ratio must be constant and complying with the value prescribed for the given product or die.

After stretching, extrusions are transported by conveyor (17) onto the saw table (18). A saw (19) serves for cutting the extrusions to the required size that may be set on the saw gauge table (20).

After having been checked (21), the products are placed into racks (22).

The most up-to-date press lines are equipped with on line aging furnaces the temperature of which can be adjusted with a high degree of accuracy and which are, therefore, suited for elevated aging temperatues ensuring the desired strength within a short time. The extruded product leaves these press lines in a state ready to be packed and shipped or surface treated. Automated press lines include, in addition, a packing station.

For the majority of extrusion plants, aging is carried out in chamber furnaces (24) not forming part of the press line. These furnaces also require a temperature setting within rather strict tolerance limits (±3 °C).

After aging, the products are finished, dressed, packed and shipped. If any of them show a defectuous contour geometry in spite of all the measures teken, they may be re-shaped by passing them through a profile rolling machine (26).

In plants of the "traditional" type, products of medium and mainly high strength but of more simple shape are produced. The operations taking place in such a plant are outlined on Fig. 3, while the grouping of equipment is shown on Fig. 4b.

Billets of high strength alloys and a part of those of medium strength arrive in homogenized and cut--up state. For these products, not intended to be quenched at the press but in furnaces or to be cold worked, it is advisable to cool the billets after homogenizing at a low rate since precipitations of large size improve their extrudability, and the solution heat treatment in the furnace provides a time period long enough for a dissolution of hardening phases. The cutting-up of such billets can generally be carried out only in homogenized state.

As the first step of the extrusion process, the billets are heated in induction, gas- or oil-fired furnaces (see Fig. 4b, item 2 or 2/a).

In order to improve output and increase productivity, tube-extruding presses are also equipped with long run-out tables, as well as water-quenching tanks and fans ensuring a good quenching for products quenched at the press and a speed-up of the cooling rate for other products in order to facilitate their handling.

This line also comprises a stretcher that is to be used in the same way as described for other press line except when the product is subsequently annealed, cold worked or solution heat treated; prior to heat treatments, the product must not be stretched or it would get a coarse structure reducing its quality or even resulting in a reject.

The cooled extrusions are transported to the saw table (18) and, after having been cut up (19, 20), they are heat treated, cold worked, dressed by other machines of the shop. For details of heat treatment, see para 1.1.3, while for those of cold working, para 1.1.4.

Dressing operations are:

- stretching,
- cutting to size,
- deburring.

Stretching serves for the same purpose as discussed above; the equipment to be used is also similar, having a hydraulic drive, but displaying a larger force. Curvedness of products of high strength and large cross-section may be eliminated by eccentric hammers or hydraulic presses rather than by stretchers. Bars and tubes may be straightened by using roll straighteners.

A saw serves for cutting to size finished products. It is provided with feeding and size-setting roll gauge table.

Deburring of extruded products is usually performed by hand or perhaps by means of manual turbo-grinders.

1.1.3 - Heat Treatment

In addition to the homogenizing performed in accordance with para 1.1.2, solution heat treatment, aging and annealing of the product are also carried out in the extrusion shop.

Solution heat treatment, quenching

Solution heat treatment and quenching operations are undertaken after extrusion or cold working in order to take the main alloying elements into solution (solution heat treatment) and stabilize this solid solution by high-speed cooling at room temperature (qenching). The supersaturated solution itself formed in this way improves the mechanical characteristics and contributes to the same process by decomposing it in the course of aging subsequent to quenching.

Solution heat treatment can be carried out in two different ways:

- at the press after extrusion; in such a case, the solution heat treatment takes place in the course of deformation; quenching may be performed by means of air, water spray or water;
- in a special furnace, usually by quenching in water.

Quenching at the press should be preffered to that in furnace, considering the resulting energy saving and quality improvement. Conditions for quenching at the press are as follows:

- a time sufficient at given temperature to dissolve the phases containing the main alloying elements must be available during billet heating and extrusion;

- the temperature of deformation, i.e., that at the point of exit from the die, must exceed the temperature of solution heat treatment;
- the speed of cooling must exceed that required for the given alloy.

Quenching methods applicable to various alloys are summarized in Table 4. If the thickness of the profile made of the same alloy grows, water spray and water quenching should increasinghly be preferred to air quenching.

Table 4 - Quenching methods and temperatures of solution heat treatment

Alloy	Quenching at the press,			Quenching from the furnace	Solution heat treatment temperature, °C
	air,	water spray,	water		
6005		x			530-550
6063	x	x			530-550
6082		x	x	x	530-550
7020		x	x	x	460-480
7075				x	460-480
2017			x	x	490-510
2024				x	490-510

The application of quenching at the press does not allow thick profiles to be manufactured. Depending upon the thickness of the product, the duration of solution heat treatment should be 0,5 to 1,50 hours for quenching from furnace.

Aging

Aging aims at dissolving the supersaturated solid solution generated by quenching into precipitates of appropriate size, type and dispersity, giving rise to important increases in the tensile and yield strength of the product. Aging may be carried out in a natural way, i.e. at room temperature, or in an artificial way, i.e., in aging furnaces. Strength values that can be attained depend upon the temperature and duration of the aging process. For highly alloyed materials, a maximum strength should not be striven after since it would result in corrosion and brittle fracture sensitivity. For information, some parameters of aging are given in Table 5.

Table 5 - Parameters of aging

Alloy	Time required for natural aging	Temperature of artificial aging, duration of holding	
6005, 6063			
6082	-	170-180 °C	3-9 h
2017, 2024	4-5 days	180 °C	16-20 h
7020, 7075	30 days	5 to 7 days at 20 °C- 100 °C 8 hours - 8 to 16 hours at 140 to 160 °C	

Annealing

An annealing operation should take place when the product has to be further deformed either because its ductility has been exhausted during coldworking or because it is required by the end user's specification. Prior to deformation, - if not taking place immediately after hot working -, materials naturally aged at room temperature shall always be annealed. Annealing should be performed at a temperature between 350 and 400 °C during a time of 3 to 5 hours for each of the alloys. Materials hardenable at room temperature should be cooled to 220 to 250 °C in the furnace.

1.1.4 - Cold Working

Further deformation of extruded products, tubes and, to a lesser extent, bars, is usually performed by the manufacturer of semi-finished products taking into consideration one of the following circumstances:

- the accuracy of the product required by the end user cannot be provided or profitably attained by extrusion - such products are, for instance, bars highly accurate to dimension produced for machining purposes;
- the dimension required by the end user, usually a thin wall, cannot be provided or profitably attained by extrusion; such products are, first of all, thin-wall tubes made of medium and high strength alloys.

Extruded bars are deformed by cold drawing only, for working of tubes prior to drawing, cold rolling may also be considered.

Usually, hydraulically-driven automatic drawing machines equipped with several dies are used in modern large plants. Diameter reduction along with wall thinning is usually performed by means of a punch fixed to the end of a mandrel; so-called floating punch tube drawing can also be considered, for alloys of low and medium strength.

Tube cold rolling is usually employed in large plants manufacturing considerable quantities of tubes of high strength. For a longer period of time, the productivity of this process had been superior to that of drawing due to the possibility of applying considerably larger reduction rates. Lately, this difference has been decreased as a consequence of using new types of lubricants developed for cold drawing having a high reduction capacity. Thus, in the case of newly projected plants, it should be carefully considered whether a tube cold roll would be capable of recovering the invested funds, even if large quantities of tubes are envisaged to be manufactured.

The lubricant used for cold working must be removed from the finished tube. As a traditional and the most unexpensive method, alkaline pickling can be applied. When, however, the product has to comply with high surface and appearance requirements, a considerable quantity of aluminium must be removed from the surface by solving, owing to the not quite uniform sticking of the lubricant. Removal of lubricants by means of emulsifiers is considered as the most up-to-date method today.

A number of extrusion shops that were established some time ago have been producing wires mainly used by the electrical industry. Recently, as a consequence of the wide-spread use of coarse wire casting-rolling mills, this activity has increasingly been abandoned by extrusion plants since casting-rolling mills are usually installed in smelters and wire drawing equipment is placed close to them. Where the volume of production is large, multi-stage non-slip or slip drawing machines controlled by processors, are usually installed. Where no strict requirements are to be met by the wire, simple single-drum drawing machines will also do.

1.1.5 - Die Provision

As regards die provision for extrusion plants, the following essential tasks arise:

- if an order for manufacturing a new product is placed that has not yet been produced, the manufacturer has to prepare the die or has to have it prepared;
- new dies have to be adjusted in order to obtain the required dimension and shape accuracy;
- after use, the dies have to be cleansed up, maintained and prepared for another use;
- when out of use, the dies should be stored properly.

Modern extrusion plants usually comprise die-making shops. Their capacities, i.e., the proportion of the requirements of the extrusion plant there are capable of meeting, are always determined by the manufacturing conditions and the industrial environment and are, therefore, subject to variation.

Die production is a process composed of several phases. Of course, its details depend upon the type of die, the process is therefore described hereby in a general way only.

Simple components of the dies (see "a" on Figures 5 and 6) as well as its overall shape contours are processed by means of traditional machining equipment, i.e., lathe and miller. Holes and undercuts ("b") in the die body may be formed by means of traditional millers but in newly established plants, computer-controlled (numerically controlled) machines are installed for the purpose. The calibration zone ("b") in the die is formed by means of spark machining equipment. Basically, two types of this equipment are being used. Flat dies suited for extruding thin-wall profiles are turned out by means of block elec-

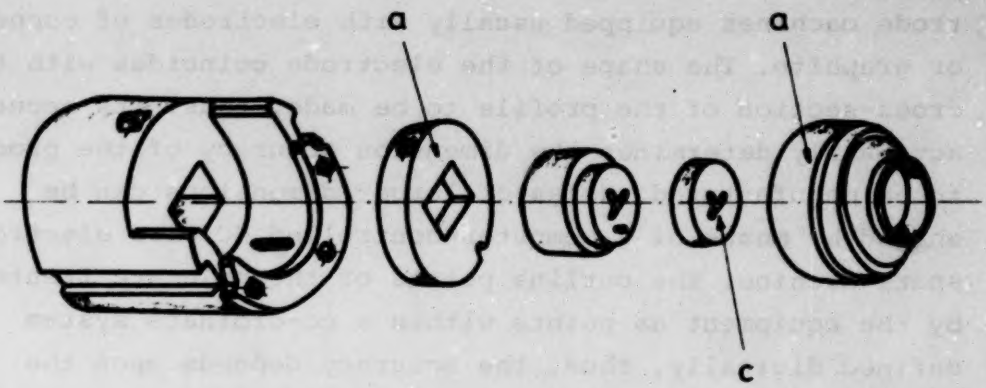


Fig. 5 Parts of a flat extrusion die

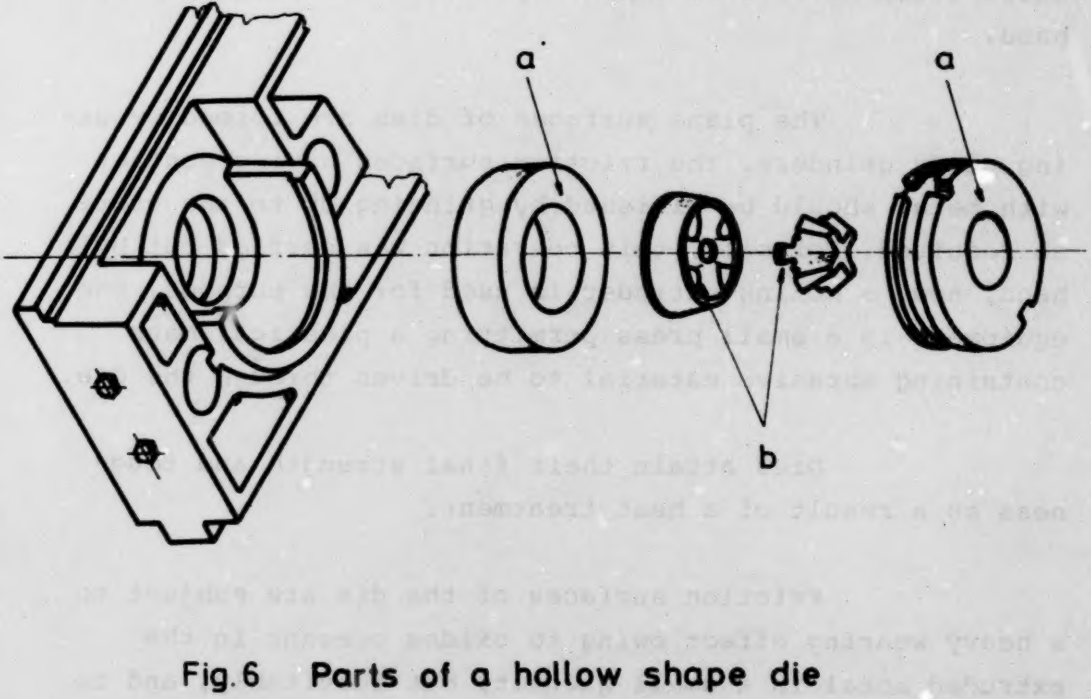


Fig. 6 Parts of a hollow shape die

trode machines equipped usually with electrodes of copper or graphite. The shape of the electrode coincides with the cross-section of the profile to be made, thus, its accuracy mainly determines the dimension accuracy of the product to be manufactured. Holes of larger dimensions can be shaped by means of a computer-controlled NC wire electrode spark machine. The outline points of the hole are treated by the equipment as points within a co-ordinate system defined digitally, thus, the accuracy depends upon the computer program. Usually, a perforated tape or magnetic card, serving as carrying medium for the information used to control the machining equipment is prepared with the help of the computer. Certain types of equipment are controlled by the computer in an on-line way, i.e., directly. In the first case, a computer is capable of servicing both the NC miller and the spark machining equipment. Were the plant not equipped with a wire electrode machine, the holes would have to be formed by means of a miller or by hand.

The plane surfaces of dies are formed by using plain grinders. The friction surfaces having contact with metal should be finished by grinding up to the state as required. Formerly, this operation was carried out by hand, now, a honing extruder is used for the purpose. The equipment is a small press permitting a plastical mass containing abrasive material to be driven through the die.

Dies attain their final strength and tougness as a result of a heat treatment.

Friction surfaces of the die are subject to a heavy wearing effect owing to oxides present in the extruded metal in a small quantity but inevitably, and to the aluminium oxide given rise to on the superficies of the calibrating zone. In order to lengthen its service life, the die surface has to be toughened. For the purpose, the method of nitriding is mainly used, carried out by means of a liquid or gaseous medium. The latter should be preferred since it provides a more resilient and durable surface layer than liquids.

The wearing off of the calibrating zone can be considerably reduced by overflowing the die exit area with gaseous nitrogen pressing out the oxigen giving rise to oxide. Introducing of liquid nitrogen into the die provides in addition its cooling and ensures possibility for further increasing of extrusion speed.

Irrespective of where they have been produced, the dies should be tested prior to using them for manufacturing purposes. Dies serving for sophisticated types of products have to be adjusted in the majority of cases. This operation should be carried out prior to producing the tough surface layer.

Maintenance and care of the dies involve the following operations: when the dies are no longer used in production, residual or adhered aluminium should be removed. For removal, soaking in warm caustic soda lye can be recommended. After this operation, blasting with small glass pearls using a liquid or gaseous carrying medium should be applied so as to obtain an entirely free-of--metal surface. Blasting with glass pearls also results in a moderate surface toughening.

The toughened surface layer should be renewed after having extruded a certain quantity so as to avoid dimensional changes. For renewal, re-nitriding should be applied.

After having been cleaned, the dies should be provided with a thin layer of lubricant - usually graphite - and stored at a location protected against dust and corrosion until they are used again.

1.2 - Choice of Technology and Equipment

1.2.1 Extrusion and Finishing

Since it is the press that constitutes the core of the investment project, as a first step of investment preparation, the press or presses to be installed should be decided upon. When choosing the press, the aspects below should be taken into account:

- the structure of industrial environment,
- the market demands expectable in the long run as regards both product mix and quantity,
- the professional experience and technical staff being at the investor's disposal.

The above aspects are rather interwoven with one another since, for example, the structure of industrial environment exerts a considerable influence on both the demanded product mix and the available technicians and services.

It is advisable, therefore, to begin the fact-finding investigation by examining the existing and planned or expectable structure of the industrial environment. An active influencing of the potential customers may be justified by desired changes. Such an influencing is of particular importance when shops utilizing the products of the extrusion plant are missing. If users exist but obtain their supplies of semi-finished products from elsewhere, quality and price (production costs) must be factors to be carefully considered so as to successfully compete with existing suppliers; in this respect, reduction is length of the transport way can be taken into consideration. If the enterprises or shops which expectedly would use extruded products are only beginning to take shape, it is advisable to familiarize prior to the starting-up of the extrusion plant, potential customers with aluminium profiles by means of similar products purchased elsewhere, probably imported ones. If there is no plant in the vicinity which would be able to utilize extruded products and if even a substitution for other products already in use e.g., substitution of window and door frames made of aluminium for those made of wood, cannot be considered, formation of complete systems suitable to be assembled by hand should be envisaged.

It will also depend upon the development stage of the industrial environment whether skilled workers and co-operating specialized firms for technical/electrical maintenance or dies production will be available as well as properly qualified and experienced staff for operating the equipment of the extrusion plant.

The above questions should be cleared since these circumstances are of definitive importance as regards the choice of the press and other equipment as well as the determination of further tasks related to the commissioning of the plant set up, e.g., purchase of know-how, training of the labour, etc.

Since these questions cannot be answered satisfactorily unless the local circumstances have been cleared up, a certain product mix will be taken for granted hereinafter, and, based upon this assortment, the general trends will be applied to the case of developing countries.

The following may be considered as most probable product mix (hereinafter: Assortment "A"):

By product types:

- 80 to 90 % profiles for architectural construction and vehicle manufacturing industries, tubes included; by far the greater part, products of thin walls and high accuracy;
- 10 to 20 % wires.

By alloy types:

- 70 to 80 % highly extrudable alloys (6063, 6005) and some unalloyed metal
- 20 to 30 % alloys with medium characteristics

For a production scheme with the above assortment, presses as follows may be recommended:

- a profile press of 18 to 20 MN (Variant 1a/1)
- a profile press of 16 MN (Variant 1a/2)

Variant 1a/1 permits a wider variety in sizes of products (the circumference of the extruded products is generally 75-80 % of that of the container), and the rate of products made of alloys with medium characteristics may increase. The composition of assortment shifts towards products of smaller size and highly extrudable alloys in the case of Variant 1a/2.

If neither of the one-press plants had a capacity sufficient to meet the expectable demand, operation of two presses would have to be considered according to Variant 2a comprising

- a profile press of 16 MN and
- a profile press of 22 to 25 MN

By putting the press of 22-25 MN into operation, the assortment of alloys can be extended and the size of products enlarged. The presses would not necessarily have to be commissioned at the same time.

In the case of all the Variants described above, manufacturing of products made of high strength alloys, first of all, rods, tubes and structure profiles, is based on purchased materials, originating from import, for instance.

If the expectable assortment of product comprises, to a large extent, products made of medium and high strength alloys, installation of two presses, namely,
- a profile press of 18 to 20 MN and
- a tube press of 30 to 32 MN

can be recommended (Variant 2b). In such a case, the expected product mix (Assortment "B") is composed as follows:

By product types:

- 50 to 60 %	profiles made of highly extrudable alloys, tubes included, and those with average characteristics
- 10 to 15 %	wires
- 15 to 20 %	tubes made of medium and high strength alloys

By alloy types:

- 40 to 50 %	highly extrudable alloys (6063, 6005) and some unalloyed metal
- 30 to 40 %	alloys with medium characteristics (6082, 7020, 5754)
- 20 to 30 %	high strength alloys (2017, 2024, 7075, 5056).

Informative data related to the presses dealt with herein are summarized in Table 6 (the diameter of containers exceeds that of the billets generally by 3 to 4 per cent).

Table 6 - Dimensions of billets used in presses; stretchers generall used (for information only)

Extrusion force MN	Dia x max.length of billets mm	Stretcher kN
16	Ø140-175x/-250x710	200
18	Ø150-185x/-265x730	200
20	Ø160-200x/-280x750	300
22	Ø170-205x/-295x800	400
25	Ø180-225x/-315x850	400
30	Ø195-240x/-340x900	1000
32	Ø200-260x/-355x950	1000

Note: x/ Mostly used diameters

The quantity of products extruded by the presses depends, to a large extent, upon the product mix, the experience and skill of manufacturer and the requirements to be met. For one- or two-shift operation, it is also to be taken into account whether or not maintenance works are carried out during the work shifts. Therefore, data given in Table 7 are for information only. Capacity calculations have been made assuming five-day workweeks, three-shift organization of labour and 20 % down time. For a one-shift operation 1/3 of the above calculated capacity while for two-shift work 2/3 of the same may be assumed.

It must not be forgotten that an economic operation of such a rather expensive equipment cannot be expected unless a three-shift working order is established. However, a one- or two-shift operation can also be considered, moreover practicable, during the early period of productive work.

Table 7 - Informative data on the output of presses and press combinations discussed herein for three-shift operation, tpy

Press, MN	Assortment		Presses, MN	Assortment	
and type	A	B^x	and their type	A	B
16 prof.	4000-5000		16 and 22 profile	9500-12000	
18 "	4500-6000		16 and 25 prof.	10000-13000	
20 "	5000-6500		18 profile and 30 tube		9000-12000
22 "	5500-7000		20 profile and 30 tube		9500-12500
25 "	6000-8000		18 profile and 32 tube		10000-12500
30 tube		4500-6000	20 profile and 32 tube		10500-13000
32 "		5500-6500			

Note: Assortment "B^x" forms part of Assortment "B": rods and tubes of medium and high strength as well as profiles of high strength.

If Assortment "A" has been chosen, the investor should install one press line and auxiliary equipment as shown on Fig.4a, (Variant 1a/1 or 1a/2). Neither the on-line homogenizing chamber nor the billet cooler form necessarily part of the extrusion line.

Should the planned capacity require the installation of two presses (Variant 2a), they would have to be placed in adjacent workshops in an arrangement as per Fig. 4a or its mirror image.

For the case of Assortment "B" (Variant 2b), the arrangement of the workshop accommodating the profile press would be analogous to that described above, while the workshop for the tube and rod press as well as other equipment serving mainly to fabricate high strength products would have to be arranged in accordance with Fig.4b.

After having come to a decision as regards both the product mix and the type of press(es) to be installed, billet preheating and homogenizing equipment should be chosen. Advantages of an on-line homogenizing equipment have been discussed in para 1.1.2; it is to be noted, however, that an on-line homogenizing furnace has a considerably larger throughput than a stationary one of the same dimensions has, since the heating time and the time required to egalize the charge temperature is considerably shortened by preheating the logs one by one. In this case, billet cooling by means of water does not cause any increase in deformation resistance because the billet is cooled to the extrusion temperature only.

On-line homogenizing furnaces and hot billet shears are used only for processing low and medium alloyed metal, i.e., only in Variants "a". For the range of high strength alloys, i.e., with the tube press as in Variant "b", these machines are unsuited.

Despite of all of its advantages, on-line homogenizing furnace cannot be taken into account unless gas or oil is available for a quick heating up of logs (the soaking furnace chamber is heated electrically). Otherwise, an induction furnace and a cut-up saw located before it should be used.

Modern billet preheating induction furnaces are usually heavy-duty short ones with a single inductor. The supplier of the furnace should guarantee a uniform heat distribution within the billet or, perhaps by using a further inductor, a longitudinal heat gradient (for highly extrudable alloys, it is more advantageous to have a higher temperature in the front part of the billet than in the rear end) permitting high extrusion rates to be applied. The advantages offered by the temperature gradient cannot be exploited unless a well-chosen technology is correctly applied and production has its regular rhythm.

In order to determine the necessary capacity of billet preheating and homogenizing furnaces, the quantity of billets needed for manufacture in the extrusion plant must be calculated: 1,3 ton and 1,45 ton of finished billets (i.e., having their extremities cut off) are required to produce 1 ton of products of Assortment "A" and "B", respectively. In both variations, 90 to 95 per cent of the billets are homogenized; for the case of Assortment "B", 30 per cent of them have to be homogenized in separate chamber furnaces, in the foundry or elsewhere.

When defining the furnace capacity, relatively great reserves should be envisaged since furnace exploitation cannot be optimized when program changes must be carried out, on the one hand, and since the formation of bottle-necks must be avoided in case the extrudability of the base material is improved or technology further developed, on the other.

Tables No. 8 and 9 can be used as references when choosing types of preheating (and on-line homogenizing) furnaces.

Table 8 - Throughput of gas-fired furnaces for preheating billets, ton/hour (preheating up to 450 °C). (On the basis of informative data given by the firm Junker)

Billet dia., mm	Length of furnace, m						
	4	5	6	7	8	9	10
150	1,2	1,5	1,8	2,1	2,4	2,7	-
200	1,6	1,9	2,3	2,7	3,1	3,5	3,9
250	1,9	2,4	2,8	3,3	3,8	4,2	4,7
300	2,2	2,7	3,3	3,8	4,4	4,9	5,5
350	2,5	3,1	3,7	4,4	5,0	5,6	6,2

Table 9 - Throughput of billet preheating induction furnaces, ton/hour (preheating up to 450 °C) (On the basis of informative data given by the firm Junker)

Value of coupling, kVA	Throughput and power consumption related to billet size in mm	Power consumption, kW	Throughput quantity, ton/hour
440	Ø180x500	400	1,4
660	Ø200x500	600	2,1
1100	Ø200x700	1000	2,9
1350	Ø250x800	1200	3,5
1750	Ø250x800	1600	4,0
2000	Ø280x900	1800	4,0

If a billet temperature other than that of 450 °C is desired, the throughput of furnace given in Tables 8 and 9 can be increased or reduced proportionally to the extent of temperature change.

Parameters for the homogenizing furnace and for the soaking chamber in the case of an on-line furnace are:

- temperature range: 450 to 650 °C

- soaking accuracy: ±5 °C
- temperature homogenity: ±5 °C

The cooling chamber installed in the vicinity of the homogenizing chamber furnace should be capable of providing controllable cooling rates.

As regards power supply for the furnaces, the average power consumption as indicated below should be taken into account for billet preheating (if an on-line homogenizing takes place, the value have to be increased by about 10 to 20 per cent):

- for induction heating: 250-300 kWh/t
- for gas-firing: 1,0-1,2 GJ/t + 5-7 kWh/t (29-34 Nm^3/t, when gas of 35 MJ/Nm^3 calorific value is used)
- for oil firing: 1,1-1,3 GJ/t (25-29 kg/t, when oil of 44 MJ/kg calorific value is used)

The data indicated above for gas- and oil-firing are valid when furnaces without recuperators are installed. Power consumption of the furnaces, when equipped with recuperators, is reduced considerably, by 30 to 40 per cent, so it is absolutely necessary to purchase such ones.

It is by no means advisable to omit billet cut-up at the press to be performed either by a saw before the induction billet preheating furnace or by hot billet shears behind the oil- or gas-fired preheating furnace. This is the only way to provide for a given product, billets cut to a length ensuring a maximum exploitation of the run-out table and a minimum of loss due to cut-up.

Theoretically, this could be implemented by providing the extrusion shop with billets cut up to the length suited for the order obtained, but this method would be infeasible for plants processing billets purchased on the market and would encounter immense difficulties of programming even for those having an own foundry. When cut up billets are used, the number of standard length variants are generally low resulting in an output reduction of nearly 10 per cent.

Billet hot shears must be capable of cutting up billets of the largest diameter to be processed by the press even if made of the alloys 6082 and 7020. The same holds for the saw, irrespective of the alloy type. Desired cut accuracy is ±5 mm, for the billet length under 600 mm and ± 10 mm for the longer ones, permissible cut angularity: max. 1^{o}.

The following should be taken into consideration by the investor with respect to the press itself and the equipment of press line:

It is not expedient to envisage the installation of a fully automated press line since all the advantages of such a plant can be achieved only by enterprises specializing in series production of similar products. It is important, however, that the press meet all the requirements dealt with in para 1.1.2 and permit the most important parameters of extruding and finishing as listed below to be set in a simple way, to be controlled and displayed automatically, furthermore, those indicated by an asterisk, even to be recorded:

- billet temperature,^{x}
- container temperature,^{x}
- rate of extrusion,

- position of hot shears,
- size of butt discard,
- pulling force of the puller,
- extent of elongation by the stretcher.

Billet temperature is taken by means of traditional thrust-in pyrometers made of a thermocouple; its control and registration is also made in a conventional manner. When taking the temperature of the container, care should be taken as to choose measurement point near the inner sleeve of the container which is not subject to staining and renders accurate and reliable results. Control and recording is made in the same manner as described for billet temperature.

It is advantageous for both the quality of the product and productivity to provide for programming the speed of extrusion or to control the speed by the temperature of the extruded product. Indispensably, however, the press must be provided with a closed loop ram speed and pressure control requiring, on its part, appropriate high speed electro-hydraulic servo valves and high speed pumps to be installed on the press. In the majority of cases (when processing highly extrudable alloys or those with medium characteristics), the speed of extrusion would increase towards the end of press cycle resulting in a reject, if such an automatic control of extrusion speed were not installed. Although this disadvantage could be eliminated by application of an ab ovo lower speed of extrusion having adverse effects on productivity or a manual reduction of the extrusion rate at the cycle end, practicable only by a highly experienced and skilled press operator.

In order to reduce the quantity of scrap to a minimum, the position of hot shears and the thickness of butt discard should be adjustable quickly and accurately and, re-adjustable to a desired value. For the purpose, remote-adjustable electronical limit switches should be used.

Speed control as well as programmable automatic controls are based upon a microprocessor technique which can also be adapted

- to store programs and/or operational experiences, e.g., those related to the given extrusion die allowing thus the microprocessor to set the desired extrusion speed, to adjust the position of limit switches, etc., upon input of the die code number;
- to store and provide data related to manufacturing, number of extruded billets, deviation from the theoretical cycle time, etc.;
- to be coupled to a computer, usually microcomputer of low cost not exceeding some thousand US dollars, which permits the operator to calculate the optimum billet length and display the code number of the defective valve or switch on the CRT of the operator's panel. This facility is of great importance, particularly when the maintenance staff has not gained sufficient experience as yet.

Another advantage of the computerized control is the fact that the entire press line can be controlled within a single station. However, if the conditions for a full computerization of the presses at the given time were unfavourable, the possibility to retrofit computerized process control at a later date would have to be kept in mind at the time of investment. Computerization of obsolete presses equipped with mechanical limit switches and servo valves would not be feasible.

When choosing further items for the press line, modern ones should be selected so as to ensure outstanding product quality and satisfactory productivity. Herebelow, various machines are described and their major desirable characteristics are summarized.

The initial table serves to receive products leaving the press which are still in hot state. Therefore, the heat-proof graphite lining must be applied in such a way so as to exclude any damage to the surface. If water quenching also takes place at the press, forming a water sump of 2-3 m length has to be provided by reversing the initial table.

The cutting-up saw or the hydraulic shears are to be placed in the vicinity of the press. In order to reduce the quantity of cutting scrap, their position should be changeable within 3-4 m along the initial table, therefore, they should be movable on rails or a chain mechanism. If a saw is used to carry out cutting-up, it should be provided with a chip exhauster (very important!) as well as with a hold-down for the product on the press side.

The run-out table is an endless chain mechanism the components of which are lined with graphite. This lining has to comply with the same requirements as that of the initial table has. The speed of the run-out table is controlled by either the press or the puller.

Characteristics of an up-to-date puller are as follows:
- speed infinitely variable or controllable by the press; the puller is usually driven by a linear motor;
- pulling force adjustable stepwise, as required by the extruded product; on presses the installation of which

may be considered the maximum pulling force of 1,2 to 1,5 kN seems to be reasonable.

- split type clamping fixture suited to follow the form of an intricate profile or profile pack without deformation; the upper jaw is composed of plates movalbe vertically independently from one another, while the lower one is toothed;
- return to home position at a high speed,
- small space requirement.

Fans may be arranged over and/or under the run-out and cooling table. As soon as the material leaves the press blown air cooling should be provided. This requirement can only be met by fans installed above the initial table. A water sprinkler can be built into the upper fans, or water fog can be generated by a separate device. Water fog provides an intensive and uniform cooling. It is particularly advantageous to use such a fog "generator" when lower fans are installed. As an alternative solution, a high-performance fan (30-40 kW) can be installed at a remote place, e.g., out of the workshop, and air is transported through airducts to the press line. By this solution, the noise level can be reduced considerably. Cooling by fans must be intensive, cooling by water spray intensive and adjustable at least by some steps.

The extrusions separated from the die are removed from the run-out table by a walking beam type lift transfer system the beams of which slide between the links of the run-out table and lift the material onto the cooling table formed by a conveyor or another walking beam system - the former should be preferred. The beams should be provided with an appropriate lining made of graphite and heat-proof plastic and shall be in a horizontal position when lift-transfer is being made so as to avoid any slipping and surface damage of the extruded products. It is also important to arrange the beams at a distance of max. 1,0-1,2 m from one another. Extrusions produced concurrently are transferred at the same time. At the end of the extrusion cycle, when extrusion cutting has taken place, the lifting-transfer operation is started by the operator; the run-out table makes a forward course and is stopped at a determined position by a phototube sensor in order to permit the lift-transfer system to remove products in a preset number of steps. In modern equipment, the products are transferred towards the stretcher over the cooling table by conveyors made of heat-proof plastic material; in less modern plants, this operation is carried out by another walking beam type handling mechanism. As regards the surface quality of the products, the conveyor system should be preferred, taking into account its higher flexibility and suitability to automation, the fact that the step distance can be set, that optimally stretchable packs can be formed, etc.

The pack of profiles to be stretched are taken over and guided between the jaws of the stretcher by another conveyor system similar to the former upon pressing a push-button on the stretcher. After having been stretched, the profiles are transported to the conveyors feeding the saw table. Care shall be taken as to keep the extrustion straight during handling.

The conveyors are installed at a distance of 1,0 to 1,2 m from one another and constructed in such a way that the idle ones can be brought into a vertical position when tail stock of the stretcher more distant from the press is to be brought closer for stretching shorter extrusions.

Up-to-date stretches are hydraulically operated and provided with jaws similar to those of the puller, the lower of which can also be moved vertically. It is of great importance - particularly when precision products are being manufactured - to have the possibility to adjust the extent of elongation (0,5 to 3,0 per cent). This can be achieved either by setting the displacement of tail stock or by adjusting the tension - the latter is a more reliable method.

Upon depressing a pushbutton on the saw, the conveyors transfer the pack of profiles to be cut up to the saw table. The rollers of the saw table are usually made of PVC, provided with free-running bearing supports and driven by a vee-belt at the bottom.

In order to reduce the noise level, the cutting-to-size disc-type saw, its hydraulic feed mechanism as well as its driving motor are located in a box-type casing under the table. To carry out a cutting-to-size, the saw is raised, guided forwards, than lowered again and returned to home position. During this time period, the material to be cut to size can be transferred over it without any trouble, up to the limiter determining its size located on the gauge table. In the course of cutting, the pack of products is fixed by means of a pneumatic hold-down covered with a soft cloth. The saw should be provided with a cooling-lubricating system and a ship exhauster.

The design of the saw gauge table is similar to that of the roller saw table and it is provided with a cushioning abutment. After cutting to size, the abutment can be tilted off and the cut-to-size product can be conveyed.

The inspection table and palletizing have a mechanism similar to that of the other conveyor systems. The racks may be loaded manually, too, the workers performing loading can be charged with inspectioning the quality of the products, particularly their surface.

If the extrusions are destined for a customer in the neighbourhood, the products can be shipped without removing them from the racks, i.e., when the racks are being loaded, paper heat-proof up to 200 °C should be placed between the layers, that must be fixed against lateral sliding, etc.

As regards the above statement according to which it is not expedient to envisage the installation of a fully automated press line, it is to be noted that some operations should, however, be automated. Such operations are: lift-transfer, adjustment of the operation of conveyor system, setting the cycle of the saw, etc.

A die preheating furnace servicing the press must be provided. An electric resistance heated chamber furnace with air-circulation having a temperature range of 450 to 500 °C should be installed.

The tube and rod press and the finishing line of the same is essentially of the same design as those described above; it may, however, be of a somewhat more robust construction and a puller is not absolutely necessary.

Apart from aging furnaces (see para 1.2.2), the presses of extrusion plants with Assortment "A" (Variants 1a/1, 1a/2, 2a) are equipped only with a profile rolling machine serving to improve the shape of the profile, first of all, the dimensions of its free openings.

In addition to the tube and rod press line, the following equipment is installed in the tube and rod extrusion shop of a plant of Assortment "B" (Variant 2b):
- heat treating furnaces (see para 1.2.2),
- cold deformating equipment (see para 1.2.3),
- finishing machines.

As finishing machines, those below should be installed:
- cutting-to-size saw, similar to that described for the press line; its feed mechanism and roller table should permit packs of sufficient width (0,5 to 1 m) to be cut concurrently,
- straightening machines: a roll straightener for tubes and rods of medium diameter (50 to 60 mm) and a hydraulic press of about 4 MN for straightening products of larger size.

The stretcher for the tube press should be so constructed as to be capable of stretching also short products of a length of max. 6 to 7 m after having been heat treated in furnace and/or cold worked.

According to the standards valid for up-to-date works, a light structure shop of 24 x 108 m = 2592 m^2 area, without cranes, is required to accommodate one profile press line and the complementing equipment. To install a tube press line and the equipment for manufacturing products of high strength of Assortment "B", a shop of 24 x 138 m = 3312 m^2 area having the same light structure must be available. (The changes of containers are provided with separate mobil cranes.) When planning the shop, it is to be taken into account that the solution heat treating and quenching furnaces are as high as 8 to 10 m, and a simple crane of 2 ton load capacity should be provided for transferring the products to be heat trated into the furnace.

On Figures 4a and 4b, the path of material flow is indicated by arrow. Billets and logs are always stored out of the shop.

The list of recommended equipment for the Variants is shown in Table 10.

Labour demands for every press per shift are as follows:

- 1 press operator
- 1 operator of the billet preheating furnace
- 1 die preparator and operator of the die preheating furnace
- 1-2 stretching machine operators
- 1 saw operator
- 2 quality inspectors and wrappers.

Material handling is performed by one worker in each shop; another worker should be kept employed as general substitute and as performer of other tasks, e.g., operation of the profile roller straightening machine.

In the hall accommodating the tube press, two persons carry out cutting-to-size and finishing of the products.

The work of the extrusion plant is managed by a technical leader as well as a foreman for each shift. The technical leader, together with the members of his staff, is responsible for the work of the plant: he schedules manufacturing and maintenance, takes care of supplying material, die and other requisites of the work and of technology development.

Table 10 - List of recommended equipment for extrusion plants, sources, informative prices

No.	Equipment facility	Possible source	Inf.price, thousand US $\$^{x}$
1.	2.	3.	4.
Variant 1a/1			
1.	Press line, complete, profile press of 18 to 20 MN, run-out table of 40-50 m length, with puller and other finishing facilities (cooling by fan, water spray or water immersion, stretcher of 200 to 300 kN, saw)	Schloemann-Siemag Ag (FRG) Sutton (USA) UBE Ind.Ltd. (Japan) Fielding and Platt Ltd (GB) Loewy (GB) SECIM (France)	Items 1 to 3 total: 2.000,-
2.	Die preheating furnace, electrically heated, with air circulation		
3.	Profile rolling machine	Sprengler Ind. GmbH (FRG)	
4.	Billet preheating furnace, throughput 2,2 to 2,4 ton/H: - induction heated, with saw before the furnace^{xx}, or - gas-fired, with on-line homogen.furnace, hot shears and billet re-cooler, or - oil-fired, with on-line homogen.furnace, hot shears and billet re-cooler.	Junker (FRG) UBE Omd- :td. (Japan) F.W. Elhaus KG (FRG) AUBURTIN (France) GRANCO (USA)	250-800
5.	Aging furnaces, 2 pcs, total output about 4000 tpy: - electrically heated or - gas-fired	Loewy (GB) UBE Ind. Ltd. (Japan) ALUTERV-FKI (Hungary)	480-600
Variant 1a/1	Total:		2.730-3.400

1.	2.	3.	4.
Variants 1a/2			
1.	Press line, complete, profile press of 16 MN, run-out table of 40 to 50 m length, with puller and other finishing facilities (cooling by fan, water spray or water immersion, stretcher of 200 kN, saw)	Schloemann-Siemag Ag (FRG) Sutton (USA) UBE Ind.Ltd. (Japan) Fielding and Platt Ltd. (GB) Loewy (GB) SECIM (France)	Items 1 to 3 total: 1.350,-
2.	Die preheating furnace, electrically heated, with air circulation		
3.	Profile rolling machine	Spengler Ind.GmbH (FRG)	
4.	Billet preheating furnace, throughput about 1,8 ton/h - induction heated, with saw before the furnace^{xx}, or - gas-fired, with on-line homogen.furnace, hot shears and billet re-cooler, or - oil-fired, with on-line homogen.furnace, hot shears and billet re-cooler.	Junker (FRG) F.W. Elhaus KG (FRG) UBE Ind.Ltd. (Japan) AUBURTIN (France) GRANCO (USA)	180-750
5.	Aging furnaces, 2 pcs, total output about 3,500 tpy: - electrically heated or - gas fired	UBE Ind. Ltd. (Japan) ALUTERV-FKI (Hungary)	460-600
Variant 1a/2,	Total:		1.990-2.700

1.	2.	3.	4.
Variant 2a			
1.	Items 1 to 5 of Variant 1a/2 (as one stage of the project)	Schloemann-Siemag Ag (FRG) Sutton (USA)	1.990-2.700
2^{xxx}	Press line, complete, profile press of 22 to 25 MN, run-out table of 40 t 50 m length, with puller and other finishing facilities (cooling by fan, water immersion, stretcher of 400 kN, saw)	EBE Ind.Ltd. (Japan) Fielding and Platt Ltd. (GB) Loewy (GB) SECIM (France)	Items 2 and 3 total: 2.100,-
3^{xxx}	Die preheating furnace, electrically heated, with air circulation		
4^{xxx}	Billet preheating furnace, throughput about 2,5 to 3,0 ton/hour - induction heated, with saw before the furnace^{xx}, or - gas-fired, with on-line homogen. furnace, hot shears and billet recooler, or - oil-fired, with on-line homogen. furnace, hot shears and billet recooler.	Junker (FRG) UBE Ind.Ltd. (Japan) F.W.Elhaus KG (FRG) AUBURTIN (France) GRANCO (USA)	250-800
5^{xxx}	Aging furnaces, 2 pcs, total aoutput about 5000 tpy: - electrically heated or - gas-fired	UBE Ind. Ltd. (Japan) ALUTERV-FKI (Hungary)	500-650
Variant 2a	Total:		4.840-6.250

1.	2.	3.	4.
Variant 2b			
1.	Items 1 to 5 of Variant 1a/1 (as one stage of the project)		2.730-3.400
2.	Press line, complete, tube and rod press of 30 to 32 MN, run-out table of 40 to 50 m length, with puller and other finishing facilities (cooling by fan, water spray or water immersion, stretcher of 10 MN, saw)	Schloemann-Siemag Ag (FRG) Sutton (USA) Ube Ind. Ltd. (Japan) Fielding and Platt (GB) Loewy (GB) SECIM (France)	Items 2 and 3 total: 3.700
3.	Die preheating furnace, electrically heated, with air circulation		
4.	Billet preheating furnace, throughput about 2,4 to 2,7 ton/hour - induction heated, with saw before the furnace[xx], or - gas-fired, for cut up billets[x], - Oil-fired, for cut-up billets[x].	Otto Junker (FRG) UBE Ind.Ltd. (Japan) F.W. Elhaus KG (FRG) AUBURTIN (France) GRANCO (USA)	400-550
5.	Aging furnaces, 2 pcs, total output about 4000 tpy: - electrically heated, or - gas fired.	UBE Ind. Ltd. (Japan) F.W. Elhaus KG (FRG)	480-600
6.	Annealing furnace, output 2500 to 3000 tpy: - electrically heated, or - gas fired.	Ebner Industrieanlagen GmbH (Austria) Gautchi Electro-Fours AG (Switzerland)	800-1.100

1.	2.	3.	4.
7. Solution heat treating/quenching furnaces, 2 pcs, 1 ton capacity each, electrically heated, for extrusions of 6 to 7 m length, output 1500 to 3000 tpy			1.700
8. Tube and rod drawing machine, 100 kN			Items 8 to 12 total: 1.000,-
9. Tube and rod drawing machine, 30 kN			
10.Tube and rod roll straightener			
11.Saw for cutting-to-size			
12.Dressing press, 4 MN			
Variant 2b	Total:		10.815-12.055

Notes: [x] Prices based on 1983 prices

[xx] In this case, either homogenized logs have to be purchased or and additional homogenizing capacity should be provided. In the latter case, homogenizing capacities required are:

Variant 1a/1: homogenizing furnace, 17 to 20 ton capacity, U.S.$ 800,000
1a/2: homogenizing furnace, 13 to 15 ton capacity, U.S.$ 600,000
2a: two homogenizing furnaces, 17 to 20 ton capacity each, total U.S.$ 1600,000
2b: two homogenizing furnaces, 25 ton capacity each, total U.S.$ 2400,000

[xxx] Items 2 to 5 of Variant 2a, supplemented with a profile rolling machine, may also form one stage of the project.

The tasks of commercial organizations attached to the extrusion plant depend, to a large extent, on the local usances and conditions and are, therefore, not dealt with herein.

1.2.2 - Heat Treatment

Heat treating equipment cannot be chosen expediently unless the quantity of products to be heat treated, the average duration of heat treatments and the requirements the furnaces have to meet are known. Furnace manufacturers can be requested to supply data concerning the average time necessary for heating the charges. On the basis of this information, the investor will be able to calculate the desired capacity of the furnaces, taking into account the envisaged number of shifts. For homogenizing furnaces, heating time takes about 3 to 4 hours; for other furnaces, see further in the proper paragraphs dealing with heat treatment. Like any other thermic equipment, these furnaces can also not be operated economically unless a three-shift labour organization is established.

Solution heat treatment/quenching

If the operation takes place at the press, no additional furnace is required. See paragraphs 1.1.2 and 1.1.3 for the conditions of quenching at the press.

Solution heat treatment in the furnace followed by a water quenching is required for Variant "B" only. About 20 to 30 per cent of alloys with medium characteristics and 30 to 40 per cent of high strength ones are usually quenched, corresponding to a product quantity of 1500 to 3000 tpy.

Parameters:

- heating time (average)	3 hours
- holding time	1 hour
- temperature range	450 to 600 °C
- accuracy of holding	±5 °C
- temperature homogenity	±5 °C

Generally, solution heat treating and quenching furnaces are vertical ones with electric resistance heating and air circulation. Under the furnace, a water tank of a depth similar to the height of the furnace is arranged for quenching purposes. When the products are ejected from the furnace into water in a vertical position, a less marked warping occurs. It is advisable to provide the furnace with a dry well through which the material to be heat treated can be fed. If the products have to traverse a water tank before solution heat treatment, the risk of corrosion is augmented.

One or two furnaces of about 8 m height and of 1 ton capacity each are required.

Aging

About 60 to 70 per cent of the products of both Assortments will have to be aged. For each press, two aging furnaces of 5 ton capacity each should be installed.

Parameters:

- heating time (average)	1,5 to 2 hours
- temperature range	100 to 200 °C
- accuracy of holding	±3 °C
- temperature homogenity	±3 °C

Both the aging temperature and, particularly, the holding time depend, to a large extent, on the alloy to be aged. As a rule of thumb, a holding time of 8 to 10 hours should be taken into account for Assortment "A" and one of 10 to 13 hours for Assortment "B".

Chamber aging furnaces are provided with electrical resistance or gas-fired heating and positioned horizontally. Both efficiency - rate of heating-up - and temperature accuracy are largely influenced by the speed of air circulation, therefore, the fans of the furnace should be of a high performance.

Annealing

This operation is required for Assortment "B" only where about 20 to 35 per cent of the products, i.e., 2500 to 3000 tpy must be subjected to annealing. In total, annealing takes 10 hours composed of 4 hours heating up, 4 hours holding and 2 hours cooling.

One furnace of 5 ton capacity is required for annealing purposes.

Parameters:

- cycle time (average)	10 hours
- temperature range	250 to 400 °C
- accuracy of holding	±5 °C
- temperature homogenity	±5 °C

The furnace is of chamber type, electrically heated or gas-fired, and positioned horizontally.

Since the above heat treatment operations form an indispensable part of extruding or of cold working operations, if any, the furnace shall be situated in such a manner as to ensure a material flow as unintermittent as possible. Accordingly, the space requirement for heat treating equipment has been taken into consideration in the framework of para 1.2.1 (Extrusion and Finishing).

One worker per furnace and shift will be required to operate the heat treating equipment.

1.2.3 - Cold Working

Manufacturers in developed countries operating one or two presses do generally not perform cold working of the products themselves, leave this task to specialized firms in this field, or big enterprises having the required equipment at their disposal.

In developing countries, however, the extruder may be forced to carry out the cold working of this products if supplying a larger area without any competitive larger plant in the vicinity. In such a case, he will have to be prepared, first of all, to produce tubes of high and medium strength, and to a smaller extent, rods and tubes of low strength. In spite of the fact that wires for electric transmission are generally bulk drawn of continuously cast stock, the necessity of wires drawn from extruded stock may also arise in the case as outlined above.

Considering the rather small quantities and the wide product mix, the use of a cold rolling tube mill is uneconomical. The loss in productivity by drawing can considerably be reduced by applying cold working lubricants containing good quality pressure-proof, i.e., reduction-proof additives. As a result of the larger extent of reduction thus available, drawing becomes a method competitive with rolling.

Considering that low quantities are concerned, it is not the aspect of productive capacity that is decisive when choosing the type of drawing machine. Drawing machines of low drawing force are not suitable for economic manufacture of large size products of high strength alloys, i.e., with adequate reductions. Robust draw benches exerting a larger drawing force are, on the other hand, too elaborate for manufacturing smaller products of good accuracy to dimension. When considering the installation of only one equipment, of course a relatively strong draw bench, say, of a 100 kN force, might be considered adequate.

Whether another draw bench is or is not to be installed, depends upon the number of the expected orders, i.e., of the product mix. If among the products to be drawn, rods and tubes of small size but high dimensional accuracy occur in a considerable proportion, an equipment of e.g. 30 kN drawing force may have to be installed.

Manufacturers of equipment for semi-finished goods production are present on the world market with highly automated hydraulically driven equipment suited for multi-hole drawing. These machines of high productivity are rather expensive, however, they cannot be profitably exploited unless used in plants where demands of considerable quantity but of narrow selection prevail. For a plant running only one or two presses and producing a large variety of goods in small lots each, rather traditional chain draw benches driven by electromotors can be recommended. The fittings for such benches are simpler than those for the other type and, consequently, also less expensive. The change of tools can be quickly performed on this equipment for producing different goods after one another.

To point the extremities of extruded stock - semi-finished products, a fast-running hammer controllable in a simple way should be used. Generally, pneumatic ones are used for the purpose. As a high-performance equipment, rotary forging machine may be mentioned. For pointing thin-wall tubes of larger diameter, however, hammers are more suited since such tubes cannot be pointed unless their wall has been dented.

The lubricant used for cold working should be removed from the finished product. For this purpose, tanks have to be installed. One of them should be heatable and contain the emulsifying solvent while the other one should serve for water rinsing. A warm water solution of laundry soda may also be used. Dissolving by caustic soda lye should not be envisaged, because, this chemical must be neutralized by acids in another bath prior to water rinsing, on the one hand, and the method does not result in an absolutely attractive surface appearance, on the other.

If there is a demand for wire manufacturing, a traditional single-drum wire drawing machine should be purchased. In this case, however, the press has to be provided with a winding-device, furthermore, it is recommended to solve the problem of extruding consecutive billets onto one another so as to obtain an endless stock product.

Equipment recommended for cold working see in Table 10 Variant 2b.

The space requirement of cold working equipment has been taken into consideration in the framework of para 1.2.1 (Extrusion and Finishing).

Required labour per shift: two workers for each draw bench; the same staff can be charged with operating both of the machines, performing pointing and degreasing, too.

1.2.4 - Die Provision

As a general rule, no extrusion plant without a die manufacturing basis of its own can be conceived, i.e., may rely upon dies originating exclusively from purchase. Experience shows that extrusion plants in developed countries produce 40 to 100 per cent of the required dies themselves, while even fully self-sufficient plants purchase dies from specialized manufacturers from time to time, first of all in order to freshen their own construction knowledge. The proportion of purchased dies to the entire quantity is depending, among a number of other factors, upon the die manufacturers' geographical distance and production standard.

Both purchased dies and those of own making should be adjusted directly in the plant or, if more complex profiles are concerned, on the press where the manufacturing takes place.

One die-setter should be employed for each press in each shift.

If an annual production of 4000 to 6000 ton (Variant 1a/1 or 1a/2) is considered, a demand for new dies amounting to 250-300 pcs/year may be taken into account. Experience shows that about 40 per cent of them become worn out in the course of a year, while 60 per cent are accumulated, i.e., not used to extrude such a quantity that would exhaust their life expectancy. Nevertheless, for a plant specialized in a narrow range of products, e.g., for one which has a delivery contract entered into with a sufficiently great enterprise in the vicinity, manufacturing window and door structures, this ratio might be inversed, i.e., 60 per cent of the dies might become worn aout in the year of fabrication.

It results from the foregoing that the die manufacturing and maintenance workshops as well as a die cleaning workshop separate from the former are to be considered as an integral part of any extrusion plant. The base equipment to be provided for the die manufacturing workshop is summarized in the Table 11. (The inf. prices are based on 1983 prices.)

A die manufacturing workshop equipped as shown is capable of producing about 100 dies a year - assuming that a one-shift working arrangement is prevailing, i.e., the above-mentioned production of 300 pcs. can be attained in the case of a three-shift working order. Productivity can be increased to a certain extent when one of the millers is numerically controlled by a computer. Such an automatic machine can be installed, for instance, when no skilled miller operator is available or the labour costs to be incurred by employing such a skilled worker would be extremely high. Both the miller and the wire electrode spark machining equipment can be controlled by the same microcomputer.

If two presses are installed in the plant (Variant 2a or 2b), the number of die manufacturing equipment does not have to be increased proportionally to the increase in demand for dies: this demand can be met by installing a supplementary miller and a block electrode spark machining facility.

Table 11 - List of recommended equipment for die-making plant, possible sources, informative prices

No.	Equipment, facility	Possible source	Inf. price th. US $
1.	2.	3.	4.
1.	Block electrode sparking machining facility (with 100 A generator, table size: approx600 x 400 x 350 mm)	CHARMY, AGIETRON (Switzerland), JAPAX (Japan)	80
2.	Wire electrode sparking machining facility - punch tape programmer	CHARMY, AGIETRON, JAPAX, FANUK (Japan)	200+50
3.	NC miller	BRIDGEPONT SERIE, FELMANN	25
4.	Vertical die miller (if no NC miller is available)	Bridgepont (GB)	6
5.	Universal miller		10
6.	All-round lathe, 400 x 1500		
7.	All-round lathe, 600 x 1500		
8.	Bench drill (max. cutter ØL 13 mm)		0,5
9.	Columnar drill (max. cutter Ø: 32 mm)		2
10.	Vacuum oven, for quenching, aging and nitriding 250 to 300 dies/year, cooling gas charge, N_2: 3,5 cu.m, the fee for nitrocarbonization licence included in the price	IBSEN (FRG), DEGUSSA (FRG)	280
11.	Plain grinder, with rotary table Ø about 1000 mm		10
12.	Compressed air turbine millers for high strength metals, Ø 3 to 6 mm, rpm: 35,000		
13.	Measuring instruments: internal/external micrometers, slide caliber gauges with watch		
14.	Files, diamond files, needle files		
15.	Glass pearl blasting equipment (dry or wet)		8
16.	2 pcs lye vats, heatable to 60 °C, volume about 1,5 m^3 each, with lye-proof lining		
17.	Vat for hot rinsing water, volume about 1,5 m^3		
18.	Honing extruder	EXTRUDER (Sweden)	25
19.	Computer:		
	19.1 - Capacity: 24 Kbyte if servicing the wire electrode sparking machining facility only	Hewlet-Packard (USA)	6
	19.2 - Capacity: 240 Kbyte if servicing both the wire electrode sparking machining facility and the NC miller	OLIVETTI (Italy), IBM (USA) TEXAS-INSTRUMENTS (USA)	60

The surface of the completed dies having contact with flowing aluminium has to be finished to a sufficient grade of smoothness so as to provide a material streaming as desired. Traditionally, this work is done by hand using abrasive cloth and paper in several stages. Since the result of smoothing may influence the streaming conditions of the material leaving the die and, thereby, also the final shape and dimension accuracy of the product, the operation will have to be carried out with a great care. Therefore, a honing extruder is one of the die manufacturing facilities that can be highly recommended although it is not indispensable.

Dies obtain their final strength characteristics, i.e., sufficient toughness and surface hardness, as a result of three types of heat treatments, namely, solution heat treatment and quenching, tempering and a kind of surface hardening of the surface having contact with streaming aluminium, so as to improve their resistance to abrasion, i.e., service life. All the heat treatments required in a die-making shop manufacturing 250 to 300 dies a year as described in this example can be carried out in a single vacuum furnace, if the nitrocarbonization method, which is considered to be the most up-to-date nowadays, is used. The furnace must be provided with an appropriate gas supply. Neutral gas (nitrogen) must be introduced into the furnace so as to cool down the workpieces, but the same gas supplying pipeline may serve to introduce gas giving rise to releasing nitrogen and carbon that diffuse into the surface. The heat treating and surface hardening assembly may be omitted when in a near vicinity, say, within a radius of 50 km, there is a reliable partner enterprise capable of carrying out all the finishing works as commission jobs.

Should the capacity of the die-making shop exceed 300 dies/year, another furnace would have to be installed in addition to that described above so as to ensure a simple and inexpensive facility for solution heat treatment and quenching as well as tempering.

It is expedient to install the die-making shop in the same building where the extrusion plant itself is located, however, they should be properly separated from one another. Delicate equipment such as spark machining facilities, for instance, should even be situated in a separate room of the shop so as to protect them against dust and to prevent spans emerging from rough-cutting to enter. The die cleaning shop should also be separated from the plant, although established in its vicinity, as near the die store as possible. Essentially, the die cleaning shop shall be equipped with three tanks for caustic solutions and rinsing water, as well as a glass pearl blasting facility.

One of the tanks contains freshly made caustic solution in the upper range of the specified concentration. This liquid serves to cleanse dies having to be quickly returned to the press. For example, if consecutive corrections must be made in the course of die adjustment or the available number of dies are not sufficient for manufacturing a large lot, dies must be returned into production without delay.

The other tank contains caustic liquid that has been used in the former for a while but that is still within the desired concentration limits. Subsequently to scheduled die changes, i.e., those not taking place out of turn, dies are cleansed in this bath at a slower rate than in the former. To remove caustic liquid from the surface, a rinsing tank containing hot water should also be provided.

Space requirement for the die-making shop:

- 200 m^2 for die manufacturing,
- 200 m^2 for die storage,
- 200 m^2 for die cleansing.

Staff requirement of the die-making shop:

- 1 worker/press.shift, for die adjustment - the die preparer is member of the staff servicing the press,
- 4 locksmiths and 6 turners, for die manufacture,
- 2 die designers charged also with programmation of die-making and numerically controlled machines.

2 - BILLET FOUNDRY

2.1 Conceptual Description

2.1.1 - Billet Production

As base material for manufacturing extruded semi-finished products, a billet made by using the semi-continuous casting method (DC) is used. Usually, the billets are of cylindrical shape, but flat ones of square cross-section are also used to produce flat products of large size. As regards the output and the quality of extruded products, the quality of the billet is characterized as follows:

- chemical analysis,
- dimensional and geometrical accuracy,
- gaseous impurities and solid ones of non-metallic nature,
- surface quality,
- structure.

Chemical composition is generally defined by the customer by specifying the desired alloy, and manufacturing is carried out in accordance with standard specifications. If not specified by the customer, chemical composition should be chosen according to the characteristics as desired for the extrusions; e.g., alloy 6063, a member of the well-deformable family AlMgSi should be chosen for anodizable products. Dimensional accuracy of billets can be defined according to the cross-sectional size and cut-up length. For instance, tolerances of a billet on a 200 mm diameter and a length of 600 to 1000 mm must not exceed ±2 mm and ±10 mm, respectively. Geometrical accuracy, e.g., a value of the allowable deviation from straight is to be specified with a view to avoid losses or unworkability.

The percentage of acceptable non-metallic impurities depends upon the type of composition, on the one hand, and the application of the product, on the other. As regards gaseous impurities, it is hydrogen the detection of which generally suffices. For the purpose, "first bubble method" apparatuses - such as Aluschmelztester (Switzerland) for instance - are mostly used. The permissible value of hydrogen content shall by no means exceed 0,10 to 0,18 cm^3 in 100 g Al for the alloy family 6xxx. The presence of solid impurities, such as oxide and slag inclusions, shall be avoided. The modern melt refining techniques and/or an "on-line" filtration taking place after the casting furnace are capable of providing the purity as required.

The quality of the cast billet surface is determinant for the output of billet production and, partially, for the quality of extruded products. The billet shall show no cracks, circular cold shuts, hot tears or porosity. As regards base material for profiles intended to be anodized, sweat on the surface of the billet and continuous reticulate microstructure in the external zone entailed by the former should be avoided on or removed from the billet surface by turning, because surface streakiness of the profile is mainly due to such faults. An adequate adjustment of and insistence on the parameters for traditional DC - such as metal temperature, level of molten metal within the mould, intensity of cooling, speed of casting - generally result in a billet surface and structure of good quality.

Because of anodization, a smooth globulitic macro and micro structure of the billets is of particular importance. As a minimum, a grain number amounting to $400/cm^2$ should be attained. Columnar crystals can also occur within a part of 10 mm thickness of the external zone which has to be completely removed from products requiring the highest level of surface quality.

For material melting and preparation to casting in up-to-date aluminium billet foundries, the use of hearth reverberatory furnaces may be recommended. There are channel or crucible induction furnaces also in use but, in general, hearth reverberatory ones find application in the majority of cases. Furnace capacity is to be defined with a view to the envisaged production volume, but it is recommended that a capacity as large as possible be striven after since such furnaces have the best indices of energetics and technology. Gas, oil or electricity may be considered as fuel for such furnaces.

Gas- or oil-fired furnaces are of robust construction. Essential requirements of structural nature are: quick charging, i.e. needing the application of large doors or a removable top, accessibility to the entire inside and a good dischargeability ensuring a laminar flow. The per hour performance amounts to 25 to 35 per cent of the charge mass and can thus be as high as 10 to 12 t/h. Specific power consumption makes, in average, 3.5 GJ/t Al that can be reduced to 1.9 GJ/t in the case of the most up-to-date types. Air fed in is preheated by a recuperator to 450 to 500 °C so as to improve heat utilization. The firing system is composed of middle-stroke burners while the flue gas speed is about 100 m/s. Performance control is carried out automatically: the temperature of metal bath controls both the fuel/combustion air ratio and the furnace space pressure. Nowadays, development of melting furnaces is aiming at a further reduction of energy consumption and a fully computerized control of the entire process.

Hearth reverberatory furnaces may also be used as casting furnaces in a so-called tandem arrangement coupled with the melting furnace at a 1:1 or 1:2 ratio; they have generally the same capacity as the melting unit has. They are fired with gas, rarely with oil or electricity. The latter is not preferred because of the sensibility to the vapours of salts which are used to treat the molten metal.

The specified chemical composition and percentage of impurities are adjusted in the melting and casting furnaces. The chemical composition is ensured by metal components to be charged in the form of ingots or scrap and by master alloys (AlMn, AlFe, AlSi, etc.) as well as by alloying additions entering the melt as pure metal (Mg, Zn, and so forth). The materials of the first and second group of components as mentioned above are charged into the melting furnace and, after having been molten and agitated, they are purified by means of flux. As flux, chlorides, fluorides, sulfates and carbonates of alkaline metals and alkaline earth metals (Na, K, and Ca, Mg, respectively) are used, generally in a quantity of 0,2 to 0,7 kg/ton. In order to obtain the desired billet structure, a grain refinement master alloy - usually AlTi5B1 - is added in a quantity of 0,5 to 2,0 kg/t. This can be introduced into the furnace itself, into the channel between two furnaces, at discharging from one into another, or into the spout after the casting furnace. The master alloy is wire-shaped in the latter case, while ingot-formed in the other two cases. The same effect is achieved by using smaller quantities of wire-shaped alloy.

Various materials and methods serving to purify the melt in the melting and casting furnaces have been used in the course of time. The methods may be classified according to the involved base process as:

- chemical (chlorine gas, C_2Cl_6, etc.),
- mechanical (inert gas, vacuum technique, on -line filtration, etc.),
- combined (inert and active gases together with filtration); depending upon requirements on the purity of the billet as well as the feasibilities of the given foundry or furnace, a gas mixture composed of 50 % Cl_2 and 50 % N_2 or C_2Cl_6 in a dose of 1 to 3 kg/t, etc., may be used to melt treatment purpose.

Combined procedures that are performed by continuously operating equipment, such as Union Carbide SNIF, Servimetal ALPUR, Conalco MINT, installed usually between the casting furnace and the casting machine are the most efficient ones. These facilities serve for introducing a gas mixture of nitrogen or argone basis containing 1 to 5 % of chlorine in a finely dispergated state into aluminium metal in order to reduce the amount of alkaline impurities and gaseous contents of the metal considerably. In this way, a sodium content of 5 µg/g and a hydrogen content of 0,1 µg/g in unalloyed aluminium can be continuously ensured.

To the specific task of removing slag and oxide inclusions, ceramic filters are particularly suitable. Two types of them have been wide-spread so far: pipe-shaped filters made of corundum (Carborundum)and plates made of chromium trioxide and alumina, foamed with polyurethan (SELEE, Conalco). Filters of the latter type are often installed in the spout (Conalco MINT).

Casting is carried out by utilizing a melt prepared as described above and analyzed. Dimensional accuracy, shape correctness, surface quality and crystal structure of the billet are essentially determined by this manufacturing phase. The semicontinuous casting machine, the attached mould and other instruments together with the specified casting parameters may result in billets of the quality as required to manufacturing.

No billet meeting the strict requirements can be produced unless a reliably operating semi-continuous casting machine is available. An essential requirement on the semi-continuous casting machine is the dischargeability of the attached furnace by a single pouring; its capacity is thus equal to that of the casting furnace. Further requirements necessary for producing straight billets are: accurate guidance without vibration, constant speed of casting, availability of the required water supply (100 to 600 m^3/h), controllability of the casting speed and water supply. Up-to-date, vertical electromechanical casting machines are driven by infinitely variable dc-motors provided with a reserve power supply unit for emergency cases. The length of logs is a programmable value adjustable with an accuracy of 1 cm. The casting machine may also be lowered by means of a hydraulic cylinder ensuring high-grade billets. However, such types are more circumstantial to set up in consequence of the need to recess the place for the hydraulic cylinder.

A traditional billet casting facility is composed of the following units:

- spouts,
- casting table,
- inner mould sleeves, lowerable bottom blocks,
- floating metal level regulators, metal distributors.

Molten metal is directed from the furnace to the mould through spouts which must be constructed in such a manner as to ensure a small heat dilatation and provide a nearly similar temperature of metal even if a great number of moulds are used. Depending upon the dimensions of the casting furnaces and the cross-section of the billets, 10 to 60 billets of circular cross-section can be cast concurrently, e.g., 60 ones of Ø 150 mm each.

The mould table form a monoblock system, i.e., the moulds have a common water space. As a result, the number of water joints may be reduced even if a lot of billets are to be cast; billets having a nearly equal size can be cast by means of the same table and the removal of the billets does also not encounter difficulties. The mould sleeves are made of a well-machinable alloy of the type 5xxx, their height varies from 60 to 140 mm according to the specified metal level, while their diameter is determined by the requirements of the extrusion plant with particular attention to the fact whether as cast or machined billets are supplied. When bulk manufacture is carried out, the dia of billets may be 100 to 400 mm.

Floating metal level regulators and metal distributors are usually made of a heat-proof material having a lower density than aluminium has, e.g., marinit, monal, etc., and form one assembly with the spout. They serve to regulate and distribute the metal quantity flowing through.

Nowadays, certain casting methods less sensible to parameter variations have been developed and put into general use ensuring a billet surface and inner structure suited for the application purposes. A method, the so-called "hot top" mould process of billet casting has increasingly been used. This method is characterized by a mould having a cooled surface with height of 20 to 30 mm above which an insulated header capable of introducing metal into the moulds without any floating distributor inside of them, by means of only one or two floating distributors in the spout. Several methods providing proper lubrication for the cooled part of the "hot top" mould are known. The most up-to-date one is that developed by the Japanese firm SHOWA using gaseous nitrogen to pulverize lubricant onto the contact surfaces of the cooled and the heat-insulated part. As an advantage of the method the profiles produced for anodizing are of excellent quality, the extrusion speed can be increased by 10 to 20 % while the time of homogenizing can be reduced by at least 30 %. This method cannot be used, however, unless extremely accurate casting facilities in good condition are available.

However, up-to-date DC machines and modern fittings are not capable of producing a billet complying with all the strict requirements unless the parameters of casting are properly set. Such parameters are:

- intensity of cooling: volume and distribution of cooling water 10 to 15 l/kg depending upon chemical composition and cross-sectional area of the billet;
- casting temperature: according to the chemical composition, liquidus temperature plus 20 °C at the discharge point of the spout;
- casting speed: 40 to 150 mm/min depending upon composition and cross-sectional area;
- level of the molten metal within the mould: 20 to 100 mm as a function of casting speed;
- temperature drop of the molten metal: 100 °C/min. with distribution of the introduced metal.

By observing the surface and structure properties of the billet, the degree of conformity of the above parameters can be verified.

Billets extracted from the pit of the casting machine must be cut off in order to remove its upper and lower extremities as well as parts of unsuitable quality. Cutting-off is made by means of rotary or band saw machines. The cut off length of the upper extremity equals to one third, while that of the lower one to half of the billet diameter. Homogenizing of cast billets is usually necessary, and can be performed in either the chamber furnace in the foundry or, in the extrusion plant during preheating them for extrusion. Subsequently, if needed, turning of billets takes place resulting in a diameter reduction of 5 to 20 mm depending upon the quality. Good quality - mostly not highly alloyed - billets need not to be scraped; in such a case, the output may be even as high as 95 %. However, when rejected billets as well as losses by cutting-off and scraping are also taken into account, the output of billet casting is 70 to 90 % under normal circumstances.

2.1.2 - Scrap Processing and Production of Master Alloys

From cutting-off of billet extremities and parts of unsuitable quality, as well as from machining, a large quantity of removed materials and chips arises.

For foundries which process several types of alloys it is recommended to sort them according to their composition. Billet scrap and rejected billets may directly be re-charged for producing the same type of alloy; they have the same value of utilization as primary metal. Profile scrap originating from the finishing lines of extrusion plants may also be re-charged, taking into account the type of alloy. In such a case, the volume of treating agent, e.g., flux, must be increased proportionally to the increase in the quantity of scrap.

Chips arising from billet turning are

usually processed in induction crucible furnaces so as to reduce melting losses. As the permissible concentration of impurities in master alloys is generally higher than that in finished products by adding alloying elements, such molten metal is usually transformed into master alloys. For products of high standard, master alloys free of impurities are required that are produced on the basis of 99,5 % Al or even 99,7 % Al primary metal.

In addition to the above scrap, a considerable quantity of slag also arises in foundries. Hot slag removed from the furnace contains 30 to 50 % of aluminium in average, but this value can attain even 70 to 80 %. In the slag cooled down slowly, nearly a half of this metal content becomes oxidized; this is why the modern foundries are equipped with special slag coolers. Metal as recovered by a multi-stage treatment and cooling can be re-charged into the melting furnace, the same holds for the coarse fraction, parts with diameter bigger than 50 mm. The fine slag fraction is used for other purposes, e.g., desoxidation of steel.

2.1.3 - Environmental Protection

Exit chlorine gas emitted by the foundry is to be considered as one of the main factors endangering the environment. Gaseous chlorine is released in the furnace or molten metal treating equipment during melt refinement. Although the regulations concerning chlorine emission are rather severe, no particular neutralization or exit gas purification is required, considering the minimum volume of chlorine emitting fluxes utilized by usual technologies. Besides, the stacks constructed for the furnaces emit gaseous chlorine at a proper height ensuring a dispersion in undangerous concentration involving no pernicious effect. Were, however, large volumes of chlorine emitted - e.g., metal treatment by means of gaseous chlorine - dechlorination and neutralization of exit gases would have to be carried out. For the purpose, equipment using a technology based upon wet absorption and neutralization by caustic soda lye is mainly installed.

A considerable volume of water is utilized by the foundry. Water is slightly heated up during the process (some °C) and becomes contaminated by grease and oil. Taking into account the necessity of water saving, recirculating systems are usually installed where water is cooled and purified. If water flows away freely, it shall be filtered and deoiled to such an extent as environmental conditions require.

It is to be noted that removal and storage of the arisen primary slag or of that of low Al-content remaining at the end of processing may, but usually does not, cause certain problems. Such slag contains a great percantage of chlorides, fluorides, sulfates, etc., which, if they penetrate into the soil, could give rise to a severe water contamination. In areas rich in precipitation, slag shall be stored in such a manner so as not to permit dissolved contaminants to enter the soil.

2.2 - Choice of Technology and Equipment

2.2.1 Billet Production

The production programme and, thus the required capacity of the billet foundry, depend upon the quantity and quality of billets necessary for producing the envisaged product mix. Considering the demands of extrusion plants discussed by the present Study, preliminary plans for foundries of three different capacities are given herebelow. These foundries are, taking into account also the expedient steps of development as follows:

- If there is one press in the extrusion plant (Variants 1a/1 and 1a/2) keeping in view profitability, it is expedient to set up a foundry for melting and casting scrap into billets. However, the capacity of a melting--casting furnace unit of optimum size is generally higher than required to process the available return scrap. Therefore, by purchasing primary metal and alloying elements, the manufacturer's own foundry can meet more than 50 per cent of the demand for billets of the extrusion plant cheaper than by buying billets and, at the same time, a more flexible adaptation to the market requirements is also feasible. The capacity of such a foundry is 4000 ton a year.
- If there is one press in the extrusion plant and the foundry has, in addition to scrap processing, to meet the whole demand for billets of the extrusion plant, the capacity of the foundry established for this task amounts to 8000 tpy
- If there are two presses in the extrusion plant (Variantes 2a and 2b) the third foundry variant having a capacity of 16,000 ton a year is intended to produce the entire demand for billets of this extrusion plant.

All three foundries produce billets of various diameters which are available for the extrusion plant with a surface as cast or, in special cases, with a turned one, in the length as cast or cut to size, in either homogenized or unhomogenized state.

The foundry also produces master alloys for its own use in ingots, made of scrap, primary metal and alloying elements.

When calculating capacities, the production volume of the extrusion plant and the foundry should be brought into line. If extrusion plant does not place sufficient orders or if any cause of idle capacity arises, the foundry should be able to sell its products, billets and master alloys, to other firms.

Technology. Aspects of Choosing the Equipment

The present Study aims at recommending a technology of manufacturing that can be implementd by using equipment and facilities capable of processing scrap arising in the extrusion plant, flexible as regards both operation and production and, at the same time, requiring a possible minimum of operator's survey and maintenance.

Charges of furnace composed of scrap cakes, ingots and master alloys, after having been prepared in accordance with the desired composition of alloy in the charging area, are loaded into the bath of liquid metal which remained in the melting furnace from the previous charge and are molten. Melting may be accelerated by agitation. After a quick analysis of the sample taken of the melt (during some minutes), the required alloying corrections are carried out. Subsequently, a refining treatment takes place. Fluxes having been used for refining and slag are skimmed off the bath surfaces into a preheated slag ladle and metal is separated from flux and slag by agitatiton.

From the melting furnace, metal is discharged by pouring into the casting furnace where a treatment by releasing chlorine takes place in order to achieve purification and degassing. Concurrently, slag is skimmed off again. The smelting bath is brought to casting temperature.

In order to analyze the charge finally, a sample of the prepared melt is taken. Of the melt of casting temperature prepared in this way, billets of the desired diameter are cast by means of vertical semi-continuous casting machine.

Depending upon the alloy, cast billets have or do not have to be homogenized. Homogenization may be carried out in the extrusion plant or in the foundry. The properties of the extremities of logs make them unsuitable for processing and must therefore be cut off. The billets arrive at the extrusion plant in the length as cast (logs) or in a cut-up condition and can be processed with a surface as cast or, in the case of highly alloyed or special products, after the surface layer was removed by turning.

A general technological outline of foundries showing all the possible operations of technology is to be found on Fig. 7. The equipment and facilities serving to implement the given technology are discussed below.

Gas- or oil-fired hearth reverberatory furnaces have proved very good for melting solid raw materials. These types are particularly suited for agitation serving to intensify melting and egalize metal as well as for other metal treatment operations. They should be provided with a large door so as to permit the charge (pig, scrap and chip, master alloys) to be quickly introduced and the metal treatment and slag skimming to be performed mechanically. The simplest of these furnaces is of stable type having a tap beneath the level of bath for discharging molten metal by gravitation. About 25 to 30 per centof molten metal form a bath that remains in the furnace and accelerates melting of the next charge considerably and minimizes melting loss. Monolithic furnace linings highly resistent to chemical effects of fluxes and mechanical ones of introduc-

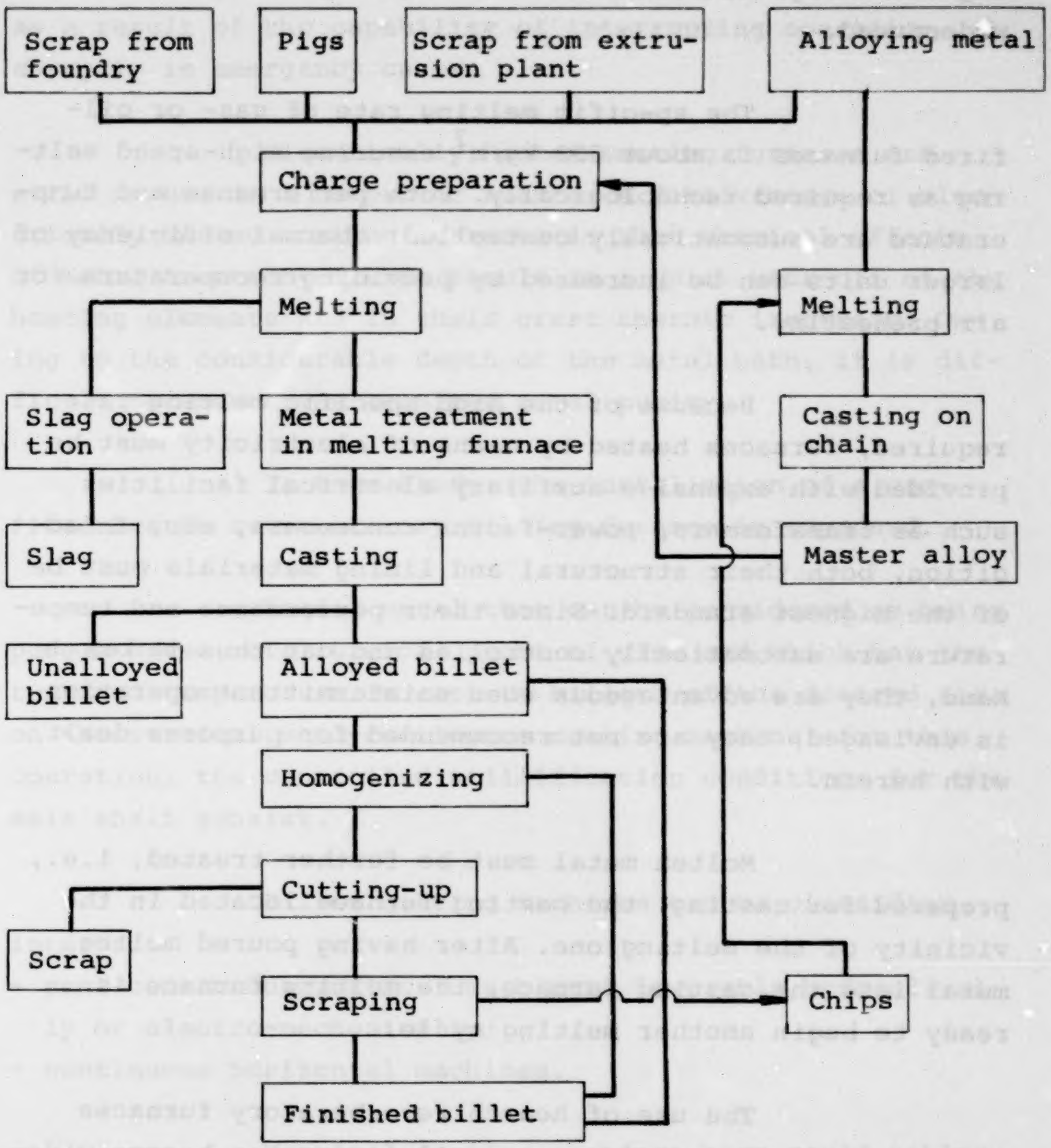

Scrap from foundry
Pigs
Scrap from extrusion plant
Alloying metal
Charge preparation
Melting
Melting
Slag operation
Metal treatment in melting furnace
Casting on chain
Slag
Casting
Master alloy
Unalloyed billet
Alloyed billet
Homogenizing
Cutting-up
Scrap
Scraping
Chips
Finished billet

Fig. 7 - Integrated block scheme of the technology used in billet foundries

ing the charge as well as to heat loading have become widespread.

The specific melting rate of gas- or oil-fired furnaces is about 300 kg/m^2 ensuring high-speed melting as required technologically. Both performance and temperature are automatically controlled; thermal efficiency of larger units can be increased by providing recuperators for air preheating.

Because of the high specific melting rate required, furnaces heated by means of electricity must be provided with expensive auxiliary electrical facilities such as transformers, power-factor condensers, etc. In addition, both their structural and lining materials must be of the highest standard. Since their performance and temperature are automatically controlled and can thus be kept in hand, they are advantageous when unintermittent operation is envisaged; they are not recommended for purposes dealt with herein.

Molten metal must be further treated, i.e., prepared for casting, the casting furnace located in the vicinity of the melting one. After having poured molten metal into the casting furnace, the melting furnace is ready to begin another melting cycle.

The use of hearth reverberatory furnaces with gas- or, in certain cases, oil-firing has become widespread for holding and casting purposes. They are either of stable or tilting design. A stable furnace can be installed at a cost which is about 30 per cent lower than for a tilting furnace, but technological requirements of casting are best met by tilting furnaces. During casting, the metal flow can be regulated with high accuracy, i.e., automatically, and a high degree of safety can be achieved as a result of the capability of interrupting operation abruptly in emergency cases.

Electrically heated casting furnaces are still in use in a number of plants. A disadvantage of electrically heated casting furnaces is that chemical effects of metal treatment fluxes result in a quick wear-off of the heating elements and in their great thermic inertness. Owing to the considerable depth of the metal bath, it is difficult to ensure the required metal purity.

In this Study, the installation of a gas-fired hearth reverberatory tilting furnace is supposed.

Liquid metal that can be considered as being pure from the metallurgical point of view and which has the required temperature is cast to billets of the desired size on the vertical semi-continuous casting machine; for this operation, the controlled solidification conditions for the melt shall subsist.

Billet casting machines can be classified into:

- semi-continuous vertical machines, lowerable hydraulically or electro-mechanically;
- continuous horizontal machines.

Vertical casting machines have mould tables with moulds arranged in accordance with the diameter of billets.

From the casting furnace, liquid metal is poured through a spout system into the moulds where solidification (crystalization) occurs as a result of intensive cooling. When the solidification progresses the bottom part of the casting table is lowered into a pit until the desired log length is attained. The capacity and the size of the mould table are determined in para 2.1. Quality conditions of manufacturing are a common function of several factors such as accuracy of guidance of the lowerable table, feasibility of smooth and stagless change of lowering speed (see para 2.1), constant metal flow and temperature within the moulds, invariability of metal level, uniformity of cooling in space and with time.

Continuous horizontal casting machines have not become widespread because of more strict requirements as regards their operation and servicing. At the same time, technological developments and constructional innovations permitting even the strictest quality specifications to be met have been incroporated into traditional semi-continuous casting methods ("hot top" moulds, electromagnetic mould, etc.).

The installation of horizontal casting machines should not be envisaged for a plant of relatively restricted capacity or even for one to be established in an environment with poor or no background of experiences in billet manufacturing.

Considering all the above aspects, an electro-mechanically driven vertical semi-continuous casting machine should be chosen for the plant.

Alloying element and impurity unevenness is egalized by homogenizing. The desired effect takes place properly if a uniform temperature distribution within the furnace space, an adequate control of heating and a very accurate steady temperature is provided. Nowadays, as a result of high degree of instrumentation and automation, gas-fired chamber furnaces can fully meet the above requirements ensuring, at the same time, a low specific energy consumption cost. Electrically heated homogenizing furnaces have thus lost their importance. Owing to impurities given rise to by it on the billet surface, the use of oil-firing furnaces should be avoided. A gas-fired chamber furnace serviced by a push bench should be chosen for homogenization, if not executed concurrently with preheating before extrusion (mostly for high strength alloys).

Homogenized billets are usually cooled outside the furnace in the air or in a special cooling chamber. Some highly alloyed materials are cooled inside the furnace.

The operation of cutting-up logs of 6000 mm length to a size suitable to be extruded should not be performed in the foundry if it can be carried out by hot shears or saws in the extrusion plant. In such a case, a saw of lower performance would also suffice to cut-off the extremities and to cut rejects to a size suited for remelting. Considering subsequently possible needs for such facilities and since the changes in the capital costs for machinery are by no means in direct ratio to the increase in performance, foundries have to be usually equipped with saws capable of cutting-to-size, too. It is recommended to install a rigid disk saw operated and fed automatically. This automation can also cover the operations of feeding-in logs and of stacking cut-up products.

If the billets have to comply with particular requirements, their surface layer must be removed. Surface removing from cut-up billets can be carried out by a machining operation like roughing. The single purpose metal-cutting machine should be equipped with a facility for feeding and removing of material.

Experience shows that it is profitable to make preparations for local production of master alloys if the capacity of the foundry is in the range of 15 to 20 thousand tpy, the more so as the volume of master alloys to be processed equals to the output of a furnace producing master alloys, on the one hand, and as it is more expedient to use chips arising in the course of billet processing for making master alloys instead of re-melting, on the other.

Should the production of master alloys be based on chip processing, a crucible induction furnace would have to be installed, considering the possible reduction in melting loss. With a view to facilitate their charging when utilized, master alloys are usually cast to ingots of 4-5 kg on a casting chain cooled by water spray.

For foundries discussed hereby, a complex slag treating would not be profitable in consequence of the small arising quantity of slag. A simpler procedure is therefore suggested which is based upon the separation of metal by mechanically agitating the slag skimmed into preheated ladles and which results in a removal of liquid metal on the bottom of the ladle.

After having solidified in trays made of cast iron, metal recovered in this way can be re-charged into the furnaces. Usually, such agitation facilities are driven pneumatically or hydraulically.

Materials to be utilized in the course of billet manufacturing are as follows:

- Base materials: scrap occurring in the extrusion plant and foundry, saw refuse chip and chip from machining, primary metal pigs, alloying metals and master alloys.

- Auxiliary materials: fluxes for trating liquid metal and grain-refining additives for obtaining the desired billet texture.

By using the foundry technology described in this Section, an output making 80 per cent of the melting furnace charge can be obtained in the course of billet production. Melting loss and slag disposition do not result in more than about 2 per cent effective loss of the melting furnace charge.

Figure 8 shows a material flow diagram illustrating the quantity of base materials utilized by the foundry.

Foundries of the capacities discussed herein are capable of producing 4000, 8000 and 16,000 ton of billets a year, when operated in a three-shift working order. As regards the practicability of such foundries, a block-wise extension of the foundry in line with the increase in demand for billets occurring in the extrusion plant that they serve has been taken into account. By expanding its hall laterally and completing the plant of 4000 ton capacity by a tandem melting-casting furnace, production can be raised to 8000 tpy. A 16,000 tpy capacity can be attained by a further expansion of the hall and the installation of a larger melting-casting unit. For the latter case, however, additional equipment must also be installed in order to enlarge the assortment of billets.

2.2.2 - Technical Description of the Billet Foundry

In line with the output of the extrusion plant, the capacity of the billet foundry should also be

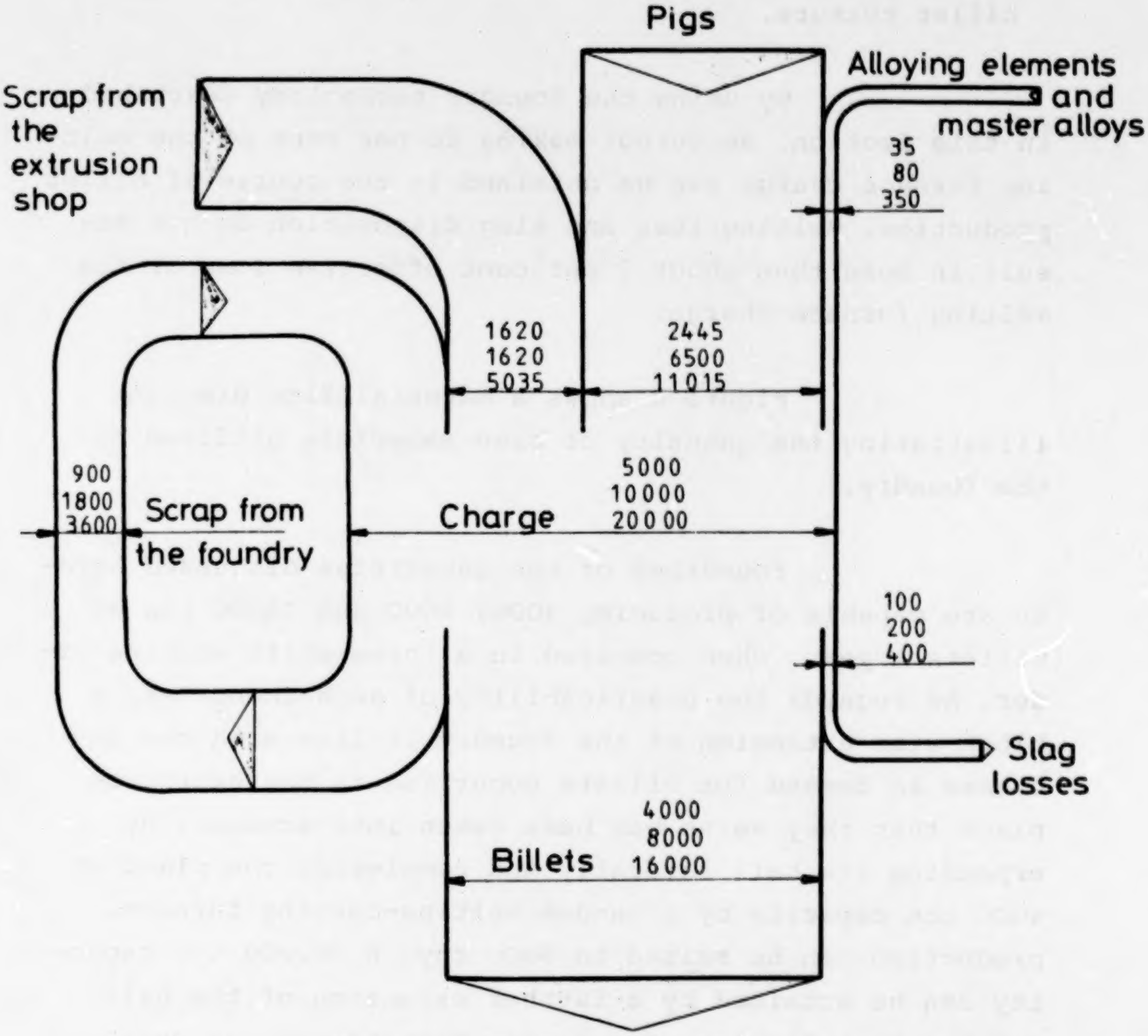

Pigs
Alloying elements and master alloys
Scrap from the extrusion shop
35
80
350
1620
1620
5035
2445
6500
11015
900
1800
3600
Scrap from the foundry
Charge
5000
10000
20000
100
200
400
Slag losses
4000
8000
16000
Billets

Fig.8 Material flow chart for the billet foundry

Note: Figures in tpy

variable. In addition to the information given in the previous paragraphs, it is advisable to study Figures 9, 10 and 11 so as to gather knowledge about equipment and expedient installation of the Variants with 4000, 8000 and 16,000 tpy capacity. For more detailed description, the Variant of 16,000 tpy will be taken as a basis herein since any required data concerning the other two variants of smaller capacity can easily be deducted thereform.

Irrespective of the complexity of the assortment, the billet foundry of 16,000 tpy is able to meet the demand for billets of an extrusion plant with two presses and, at the same time, it can fully process the arisen scrap. If a step-wise installation has been decided upon, the capacity of melting-casting units may be different (as shown on Fig.s). If installation takes place at once, it is advisable to use two melting-casting units of 15 ton capacity each. Although output data of a melting-casting unit of large capacity are favourable, two units of smaller capacity can meet the demands of an extrusion plant with a large product scale far more flexibly than the former. The circumstance should not be disregarded when deciding on capital investment.

Assortment of produced billets:

size: Ø140 to 355 mm, length 6000 mm as cast or 710 to 950 mm as cut up; surface as cast or with removed surface layer.

alloy: 40 to 50 % highly extrudable alloys (6063, 6005) and some unalloyed metal; 30 to 40 % alloys with medium characteristics (6082, 7020, 5754); 20 to 30 % high strength alloys (2017, 2024, 7075, 5056) (30 % to be homogenized in the foundry).

master alloys: AlFe, AlSi, AlCu, AlMn.

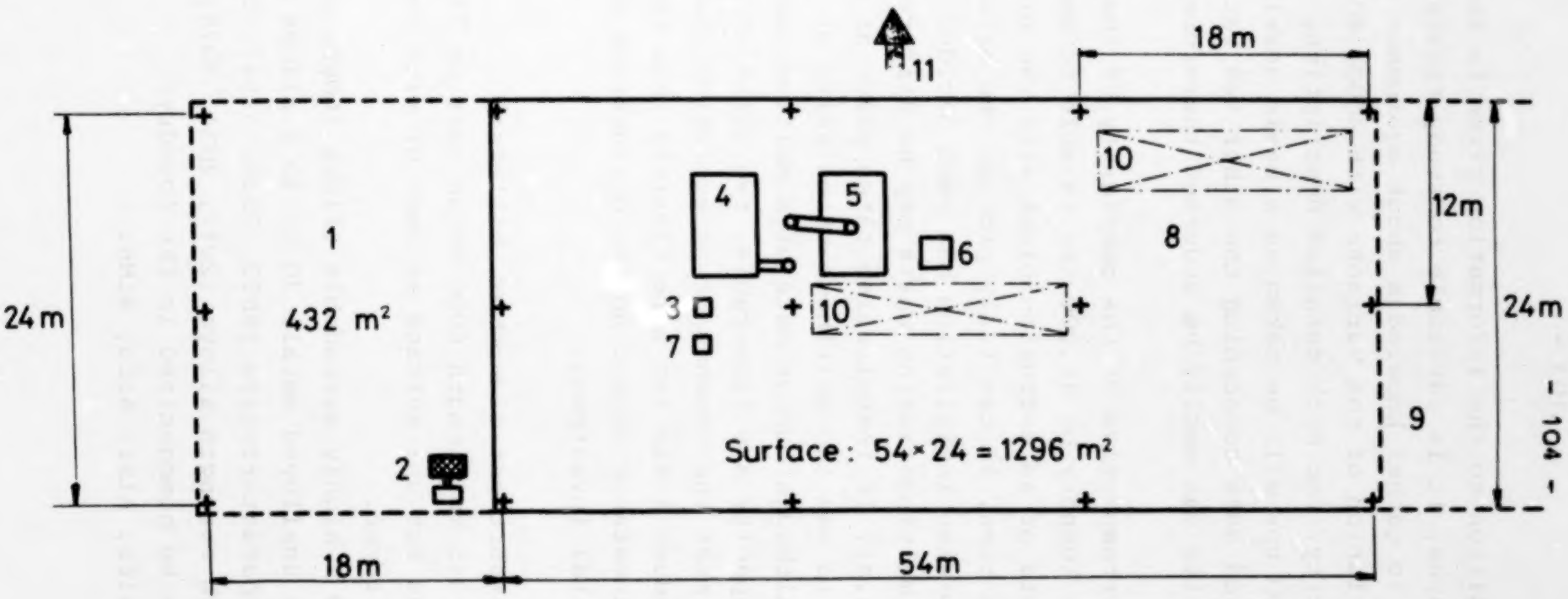

11
18 m
1
432 m²
24m
2
3
7
4
5
6
10
10
8
12m
24m
9
Surface: 54×24 = 1296 m²
18m
54m

Fig. 9 Layout of a billet foundry of 4000 ton/year output

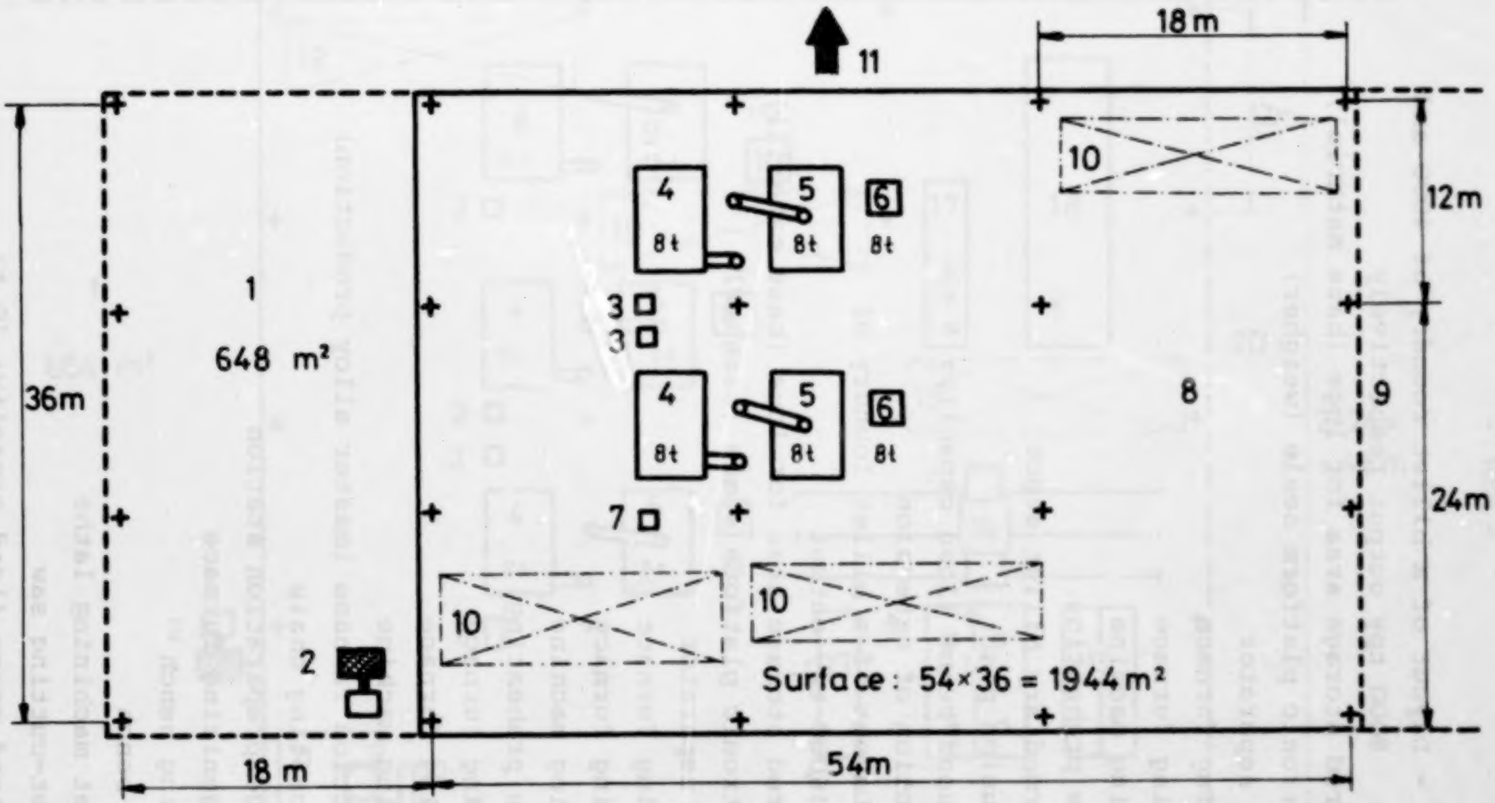

18m
11
1
648 m²
36m
2
3
3
4
8t
5
8t
6
8t
4
8t
5
8t
6
8t
7
10
10
10
8
9
12m
24m
Surface : 54×36 = 1944 m²
18 m
54m

Fig.10 Layout of a billet foundry of 8000 ton/year output

Fig. 9-10 - Layout of a billet foundry of 4000 and
8000 tpy output respectively

1 - Covered storage area for logs (base material)
2 - Electronic platform scale (weigher)
3 - Slag separator
4 - Melting furnace
5 - Casting furnace
6 - Casting machine
7 - Ladle preheating
8 - Intermediary billet stock
9 - Extrusion plant
10 - Overhead crane (load capacity: 8 t)
11 - Direction of extension

Fig.11 - Layout of a billet foundry of
16,000 tpy output

1 - Covered storage area for logs (base material)
2 - Electronic platform scale (weigher)
3 - Slag separator
4 - Melting furnace
5 - Casting furnace
6 - Casting machine
7 - Ladle preheating
8 - Melting furnace
9 - Casting furnace
10 - Casting machine
11 - Induction furnace (master alloy production)
12 - Pig casting chain
13 - Charge preparation station
14 - Homogenizing furnace
15 - Cooling bench
16 - Push bench
17 - Billet machining lathe
18 - Billet-cutting saw
19 - Overhead crane (load capacity: 10 t)
20 - Extrusion plant

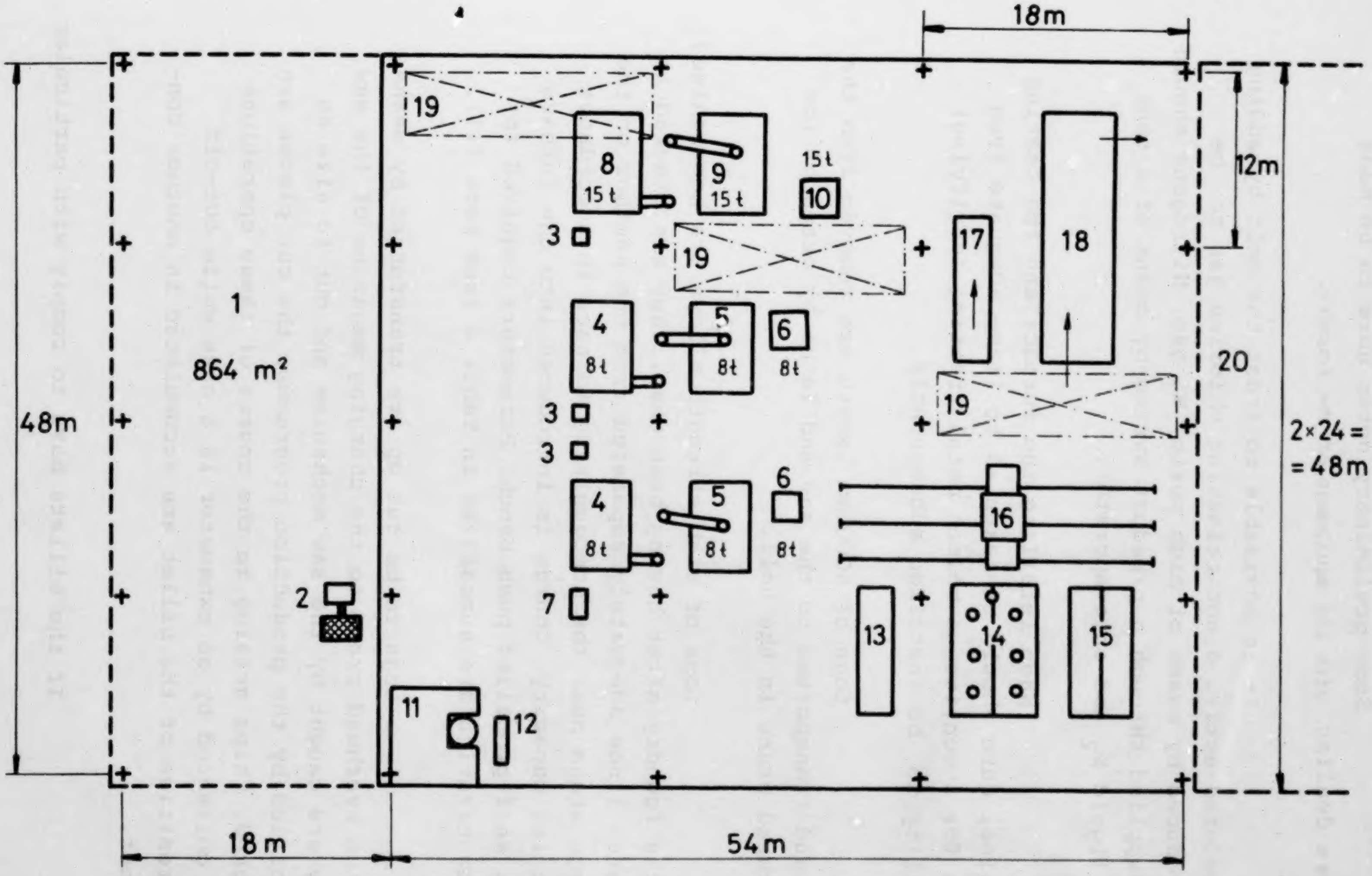

18m
12m
48m
1
864 m²
2
3
3
3
4
8t
4
8t
5
8t
5
8t
6
8t
6
8t
7
8
15t
9
15t
10
15t
11
12
13
14
15
16
17
18
19
19
19
20
2×24 =
= 48m
18 m
54m

Fig.11 Layout of a billet foundry of 16000 ton/year output

Some preliminary notes have to be made before dealing with the equipment of the foundry.

It is advisable to treat the melt by adding a powdered active agent releasing chlorine gas to be introduced by means of high purity N_2 gas. Nitrogene should be supplied through a pipeduct system by means of a tank for liquid N_2 and an evaporator.

When istalling the furnace and the casting machine, care should be taken as to leave adequate free area for a continuous molten metal treating (purifying) facility to be installed subsequently.

Logs of 6000 mm length are removed from the pit and transported to the saw and lathe by means of the overhead crane in the hall.

Logs of high strength alloys are homogenized in the foundry after having been cast. They are stacked in several lines adequately separated from one another on the charge stage near the homogenizing furnace in accordance with its capacity. Charge is introduced into the furnace by a self-propelled push bench. Parameters required for homogenization are summarized in Table 2 (see para 1.1).

Logs to be cut up are transferred by means of the overhead crane to the charging magazine of the saw. They are caught by the saw mechanism and cut to size as specified by the production programme; the cut pieces are stacked. Chips arising in the course of these operations are collected by an exhauster in a case while cut-off extremities of the billet are accumulated in another container.

If the billets have to comply with particular requirements, their surface layer must also be removed. This is achieved by means of the lathe-type machine. Cut-up billets are transported by an overhead crane to the lathe where they are mechanically loaded to the machining facility, scraped and stacked. Scrap resulting from this operation is collected in appropriate cases while the stacked billets are conveyed to the extrusion plant.

Chips arising in the extrusion plant and in the foundry is melt in a crucible induction furnace and, after adding various alloying metals, used to produce master alloys. For the purpose, a crucible induction furnace of 1 ton capacity should be used. In order to accelerate melting, it is expedient to operate the furnace with remained melting bath. Pigs of a shape facilitating their charging are cast from the liquid metal on a casting chain cooled by means of water spray. A composition analysis of each charge forms also part of master alloy production. Pigs are used for alloying purposes in the melting furnaces.

Major facilities of the foundry and their important technical characteristics are as follows:

- Electronic platform scale
  - weighing capacity: 5 tons
  - weighing accuraca: ±0,01 %
- Diesel truck for furnace charging
  - type: front fork
  - load capacity of revolving head: 1000 kg
  - length of revolving head: 1500 mm
  - load capacity of truck: 8 t
  - cycle time of charging: 500 kg/min.
- Melting furnace, 8 ton
  - type: fix hearth reverberatory furnace
  - combustible: natural gas or fuel oil
  - installed heating performance: 260 m^3/h natural gas
  - melting performance: 2 t/h

bath surface: 8 m^2
bath load: 250 kg/m^2.h.
charge time: 6 h
volume: gross 8 t
net 6 t
remained melting bath: 2 t
movement of charging door: controlled from the truck
refractory lining: monolithic
crown design: suspended
regulations: firing, gas/air ratio, space pressure
normal capacity: 4000 t finished billets a year

- Casting furnace, 8 t
  - type: heart reverberatory
  - movement: hydraulically tilted
  - combustible: natural gas or fuel oil
  - installed heating performance: 10 m^3/h natural gas
  - bath surface: 8 m^2
  - charge time: 6 h
  - refractory lining: brickset, lined with magnesite bricks
  - fume removal: through individual stack
  - regulation: gas/air ratio
  - nominal capacity: 5800 ton finished billet a year
- Casting machine, 8 t
  - type: vertical, semi-continuous
  - movement of casting table: electro-mechanical;
  - loadability: 8 t
  - mould table dimensions: 1200 x 1200 mm
  - casting speed: 0 to 200 mm/min., infinitely variable
  - cycle time of casting: 2,5 to 3 h/charge
  - charge casting: by one pouring
  - regulation: stabilization of casting speed
  - cooling water consumption: 75 m^3/h
  - mould design: closed water chamber with adjustable water slot

nominal capacity: 12,800 ton cast billets a year

- Melting furnace, 15 t
  - type: hearth reverberatory, fixed
  - combustible: natural gas or fuel oil
  - installed heating performance: 520 m^3/h
  - melting performance: 4 t/h
  - bath surface: 16 m^2
  - bath load: 250 $kg/m^2.h$
  - charge time: 6 h
  - volume: gross 15 t
  - net 12 t
  - remained melting bath: 3 t
  - nominal capacity: 8000 t finished billets a year
  - otherwise: see melting furnace 8 t
- Casting furnace, 15 t
  - installed heating performance: 20 m^3/h natural gas
  - both surface: 16 m^2
  - volume 15 t
  - nominal capacity: 10,800 t finished billets a year
  - otherwise: see casting furnace, 8 t
- Casting machine, 15 t
  - loadability: 15 t
  - mould table dimensions: 1600 x 1600 mm
  - cooling water consumption: 150 m^3/h
  - nominal capacity: 24,000 ton cast billets a year
  - otherwise: see casting machine, 8 t
- Furnace for billet homogenizing
  - type: chamber type, natural gas-fired
  - installed heating performance: 100 m^3/h natural gas
  - flue removal: through individual stack
  - dimensions of cahmber: 4100 x 2600 x 7000 mm
  - mass of charge: 25 t
  - movement of charge: by means of self-propelled push bench, running on fixed path
- Furnace for producing master alloys

type: tilting crucible furnace
mode of heating: induction
volume: gross: 1000 kg
charge: 500 kg
installed power: 250 kW
specific energy consumption: 525 kWh/t
cycle time: 8 h/charge
nominal capacity: 3000 t master alloy a year

- Billet machining lathe:
  machinable billet size: Ø100 to 400 mm
  length: max. 1200 mm
  capacity: 5000 t a year
  with mechanical billet loading and removal
- Billet saw
  type: circular saw with rigid disk, for billet cutting-up
  billet size: as cast: Ø140 to 2500 mm x 6000 mm
  cut up: Ø140 to 250 x 300 to 1200 mm
  cutting range: Ø70 to Ø470 mm
  net cutting output: 4500 cm^2/min.
  automatic billet charging magazine
  automatic cutting-up, programmed
  automatic stacking facility for cut billets
  cutting performance: max. 15 t/h depending on the size of cut-up billet

- . -

A list of the machinery for the billet foundry and the estimated capital expenses are summarized in Table 12.

Some manufacturers and sellers of major equipment and facilities for billet foundry are listed below.

Melting and casting furnaces:

GAUTSCHI, CH 8274 Tagerwillen, Switzerland
STEIN-SURFACE, 91015 Evry Cedex, France
ALUTERV-FKI, 1389 Budapest XIII., Pozsonyi ut 56, Hungary

Casting machines:

GAUTSCHI COHAMA GmbH, Frankfurt/M, Zeil 65-69, F.R.G.
DEMAG, Duisburg, Königstrasse 57, F.R.G.
WELLMANN, Darlaston, Wednesbury WS Lo8LG, U.K.
ALUTERV-FKI, 1389 Budapest Pozsonyi ut 56, Hungary

Billet saws:

KLINGELNBERG, Remscheid, POB 100560, F.R.G.
OLIVER, Grand Rapids, Michigan, 49504, U.S.A.
WELLMAN, Darlaston, Wednesbury WS 108LG, U.K.
BERGER, 38130 Echirolles, 24 rue de la Paix, France

Homogenizing furnaces:

CFI, 93104 Montreuil, rue des Grand-Pecheurs
STEIN SURFACE, 91015 Evry, France
GAUTSCHI, CH 9274 Tagerwillen, Switzerland
BIRLEC, Adridge, Walsall W 89 8BX, U.K.
WELLMAN Incandescent Ltd. London, Swiwils Wilton Road, U.K.
EBNER, A-4021, Linz-Donau, Austria.

Table 12 - List of machinery and estimated prices of the equipment for a foundry of a 16,000 tpy capacity
(FOB port of the continent where manufactured. Prices based on 1983 prices)

No.	Equipment or machine items	Pcs	Unit price	Total
			Thousand U.S.$	
1	Melting-casting unit, 8 t - melting furnace - casting furnace - casting machine	2	750	1500
2	Melting-casting unit, 15 t - melting furnace - casting furnace - casting machine	1	950	950
3	Equipment for ladle preheating, double arm, with 4 ladles	1	20	20
4	Slag separator	3	10	30
5	Induction crucible furnace, 1 ton, with pig casting chain	1	250	250
6	Tool preheating furnace	1	10	10
7	Furnace for billet homogenizing, 25 t, with push bench	1	1200	1200
8	Billet saw, with charging magazine, stacking facility	1	400	400
9	Billet lathe with charging magazine and removing facility	1	150	150
10	Equipment for material handling - 1 pc platform scale, 5 t - 6 pcs charging truck - 3 pcs overhead crane			1350
11	Laboratory equipment and facilities for quick analyzing	1	250	250
12	Other machinery and equipment			140
	Grand total:			6250

The shop hall is a modular steel structure with the module dimensions of 12 x 18 m equipped with cranes. The useful interior height makes 12 m over the casting area in order to provide a natural ventilation and to permit the overhead crane to remove, in vertical position, billets of 6 m length from the pit. Flue gases leaving the melting and casting furnaces are emitted by individual stacks through roof piercings located between the posts so as not to impede crane operation. It is advisable to calculate with a floor loading of 5 t/m^2. Expectable building costs are summarized in Table 13.

Table 13 - List of buildings for the foundry

No.	Item	Capital cost Thousand U.S.$
1	Shop hall for the foundry, 54 x 48 = 2592 m^2	960
2	Raw material storage, covered 18 x 48 = 364 m^2	100
3	Foundations for machinery, public utilities' networks, floor of hall	500
4	Stacks offtaking flue gas	240
5	Other building constructions	80
	Buildings, total	1900

Topics related to the plant's power supply and public utility networks are discussed in para 5.2. Manufacture and maintenance of casting tools should be considered as questions of the foundry's organization.

Information on the staff requirements of the foundry are given in Table 14.

Table 14 - Staff required for three-shift operation of the foundry

Sphere of activity	Plant of an output of		
	4000	8000	16000
		tpy	
Shop-manager	1	1	1
Production leader	-	-	1
Foreman	3	3	3
Clerk	3	4	6
Laboratory assistant	4	4	5
Tool repairman	2	5	5
Charge preparator	3	3	3
Truck driver	6	12	17
Craneman	6	9	9
Melter	3	3	3
Melter labourer	3	6	9
Caster	9	18	21
Homogenizer	-	-	2
Saw operator	-	-	1
Unskilled worker	4	4	5
Total:	47	72	93

3 - ANODIZING PLANT

3.1 Conceptual Description

Anodizing is an expensive operation as regards both the non-recurrent expenditures: establishing a new plant, and the recurrent ones: energy and chemicals consumption, etc. Experience gained in the course of development operations during the last two decades shows that a tendency to reduce costs of both types has been prevailing, leaving unaffected, moreover, even improving quality and product mix.

3.1.1 - Technologies

All the anodizing technologies essentially involve three groups of operation:

- surface pre-treatment
- anodization and colouring (dyeing)
- post-treatment.

Surface pre-treatment may be carried out in three ways: mechanical, chemical and electro-chemical. Among them, mechanical and chemical treatment are discussed herein; it is the chemical one that can be considered as the method of the future.

Because of its high demands for both equipment and labour, but also as a result of improvement of surface quality achieved by extrusion, mechanical pre-treatment, e.g., grinding, is used only if particularly strict requirements are to be met by the surface. Chemical pre-treatment - most expediently, matt etching - is fitted in tank with other operations of the technological process such as degreasing and desoxidation. This is the method requiring the lowest costs to be incurred and resulting, at the same time, in a smooth and attractive surface, so-called "satin surface".

An immense development has been taking place in the field of anodization and colouring as well as their combinations. Since a number of variations are feasible, a classification is indispensable. The following groups will be discussed herebelow:

- colourless anodizing,
- integral colour anodizing,
- absorption dyeing,
- electrolytic colouring.

Colourless oxide coating produced by anodizing is a powerful protection against corrosion and wear-off. This treatment should therefore be taken into account both as one which improves the products' quality and one which produces a subcoat for colouring. It is a relatively unexpensive method used in every plant.

There are several methods resulting in very good integral coloured coatings such as DURANODIC 300 (U.S.A.), AUTOKOLOR-HSH (Hungary) and CORUNDALOR (F.R.G.). Because of the high expenditures for energy and chemicals, integral colour anodizing has gradually been abandoned by manufacturers.

Post-colouring of colourless oxide coatings by means of organic dyestuffs permits an unlimited colour range to be considered. However, such dyestuffs are of poor light-fastness, except certain products of SANDOZ (Switzerland).

Owing to the low expenditures of energy and chemicals involved, the selection of three primary colours and their shades as well as the durability of colour shown by coats coloured by means of the method, electrolytic colouring has increasingly been spread during the last decade. Methods and procedures of TRUECOLOUR (U.S.A.), ELEKTROKOLOR (Hungary) and ALMECOLOR (F.R.G.) are widely known.

Combinations of electrolytic colouring and absorption dyeing have also been utilized.

Post-treatment must be performed as an indispensable finishing operation of producing anodized colourless and coloured coatings. Sealing treatments carried out by means of vapour or hot water as well as application of plastic layers using various methods can be taken into account. Owing to the low costs and proper weather proofness, hot water sealing is preferred by the majority of manufacturers.

Series of operations that can be considered as optimal - as regards quality, product mix and expenditures - serving to surface treating extruded aluminium products to be used by the building industry would be: degreasing - matt etching - desmutting - anodizing - electrolytic colouring - sealing. Between main operations, of course, auxiliary ones such as rinsing by water take place.

3.1.2 - Equipment

An anodizing equipment is composed of technological tanks arranged in series. The product to be anodized shall be mounted onto a beam and moved along the tank series by a crane. Depending upon the applied technology, sources of currant, cooling and heating facilities, control systems, water treating system, stores for chemical and pumps, as well as air treating facilities form also part of the plant. Usually, the equipment is controlled in an automated way except for the operations of racking and unracking extrusions which are performed by hand. As regards the position of profiles in the tanks, plants operated vertically and horizontally are conceivable; the latter ones have become common.

According to the size of equipment, the unit capacity of a plant may range from 2000 to 4500 tpy. Because of the high specific construction expenses, plants having a capacity smaller than the above lower limit cannot be best economical when profile anodizing for building industry purposes is envisaged. Capacities exceeding the upper limit can be attained by multiplying the smaller series capacity; in such a case, this multiplication will, owing to a reasonable designing, cause a lower than linear increase in the capital costs of auxiliary facilities. Considerable operational advantages also suggest to choose a capacity falling within the above range.

In accordance with international practice, the average length of constructional profiles for building uses should be 6000 mm while their average specific surface, i.e., the surface per unit of the mass to be anodized, at least 0,375 m^2/kg. Taking into account the production volume and product mix for different Variants of extrusion plant, a mass in the range of 3000 to 6000 tpy to be anodized may be expected. It is recommended to install a plant (tank series) of 3000 tpy unit capacity - taking into consideration the size and number of tanks. The capacity can be redoubled by installing another line.

As regards the operation of equipment, we are dealing herewith with automatic control only. The process control ensures the standard quality level for several technological variants and for the case of a flexible product mix as per the demands of the market and it results to a lesser extent in savings in labour which is usually the main consideration for application of automation. Even in this case an intervention by the operator will be necessary for survey and quality control and in exceptional situations as well, in addition to the operations of racking and unracking extrusions, as discussed above.

The automatic operation system can be described by a diagram of way/time type of the cranes performing technological material handling.

In respect of quality requirements and control, it must be emphasized that any equipment capable of producing a given technological product scale cannot be best exploited unless operated within specified quality and assortment limits.

For the quality level, international and local provisions shall be taken into account together with the market situation. The quality of the finished products has to be checked by examining colour, efficiency of sealing and thickness of anodized oxide coat. The end products's quality depends upon the quality of the initial semi-finished goos (extruded profile) and parameters of the surface treatment that has been carried out.

Consequently, the quality control system's work should rely upon determination of the initial state, the steps of technological process (analysis of solutions) and the quality of final products. The relative quality control should be performed in accordance with internationally accepted standards (e.g., ASTM).

The effects of acidic and alkaline technological solutions as well as of vapours and aerosols shall be pondered from the point of view of environmental protection. Sewage treating facilities may be based upon the principle of bypassing or recirculating. Facilities using the latter method are preferred for both economical and environment protection efficiency. In such a facility, rinsing water is purified by ion-changing; therefore, treatment of concentrated sewage and supply of fresh water are only to be taken care of.

Vapours and aerosols should be removed from the immediate vicinity of technological tanks and from the atmosphere of the plant by exhaustion; in order to comply with the provisions of environmental protection legislation, the dangerous materials must be caught (separated or precipitated).

3.2 - Choice of Technology and Equipment

When establishing an anodizing plant, creation of optimum market conditions should be striven after. For the same,

- a large assortment and optimum quality and
- reasonable operational circumstances

are indispensable.

Since these requirements are, in a sense, in contradiction with one another, a compromise must be made that presupposes a consideration of several aspects such as product mix, capacity, rather cheap establishing and operation of the plant, feasibility of extension and availability of infrastructural fundamentals.

When deciding on the equipment's capacity, it should be kept in mind that, according to the international standards of building industry, an oxide coating thickness of 10 to 15 or 20 to 25 µm must be provided on the product when intended to be utilized indoors or outdoors, respectively. As regards product mix, it is advisable to produce colourless goods, i.e., of natural aluminium colour, in a proportion of 60 to 70 % while coloured anodized ones in 30 to 40 %. If two different electrolytic colouring processes are used providing three shades of colour each, an assortment of seven colours: six shades plus the natural colour, can be offered. Theoretically, considering that two methods of surface pretreating - normal and matt etching - are available, 14 variants arise, therefore the use of about 5 to 8 technological variants can really be expected. Using several electrolytic colouring processes light, medium and dark shades of grey-black, goldish--brown and red-claret colours can be ensured (ELEKTROKOLOR).

Any deflection from the above assortment causes a 10 to 15 per cent change in both non-recurrent and recurrent expenditure and a 5 to 30 per cent one in marketing incomes. Although it is generally accepted that an anodized product of higher degree of processing, e.g., a coloured one, represents a higher marketing price level, the structure of the expectable demand inevitably enforces a compromise and even determines the optimum profit.

Considering either the side of investments or the aspects of production, it seems expedient to install such capacities which, within certain limits, can easily be converted to use different technologies of anodizing and to be extended, without difficulties, ensuring thus a flexible adaptation to the changed demands of the market. In such a way, for instance, an increase in proportion of coloured products as compared to the planned figures would be practicable resulting in - because of the higher unit price - a larger profit even if the production volume as a whole were reduced. Should, for instance, a future extension of 50 or 100 per cent be envisaged already at the time of the establishment of the plant, incurring the risk of untimely investment, i.e., should the facilities and public utility networks required by the entire capacity resulting from the extension be installed well in advance or, at least, planned and should the location of basic equipment to be established on the occasion of extension be foreseen, the capital costs of extension would amount only to 75 to 95 per cent of those of establishing of a completely new plant.

The infrastructural preconditions for an anodizing plant are the same as for other types of plants, namely: power supply, public utilities, road-system, water supply. For anodizing shops, water is primordial since operations of both anodizing and surface pre-treatment need big volumes of fresh water and the requirements in respect of its quality are also strict. In addition, a considerable volume of sewage will arise.

The quality of the available water will govern the preliminary purifying operations to be carried out, while the sewage treatment methods to be applied will depend upon the quantity of available water. These figures will thus have a considerable effect on capital and operational costs.

As regards the technical and economical aspects of establishing an anodizing plant, it is to be noted that such a shop may be instituted even without setting up a foundry or an extrusion plant; such shops perform, as commission work, anodizing of profiles extruded by other firms or, as another example, a building enterprise carries out the surface treatment of parts to be installed in buildings constructed by itself. Exploitation of capacities and amortization of capital expenditures are the factors determining whether the investment costs to be incurred for establishing the anodizing plant could prove profitable or not.

The extrusion plants discussed herein should be provided with one or two anodizing lines with a capacity of 3000 tpy each.

3.2.1 - Data Defining the Type of Equipment to be Installed

Length of profiles	max. 6400 mm
Dia of the circumscribed circle	max. 300 mm
Average specific surface of profiles	0,375 m^2/kg
Typical alloy and temper of profiles	6063 T5
Working hours	4100 h/year (3 shifts)
Productive capacity	3000 tpy (1 150 000 m^2/year)
Repartition of production	colourless anodizing 60-70 %, electrolytically coloured anodizing 30-40 %
Maintenance time, total	200-300 h/year
Control	automated, 7 base programs

3.2.2 - Equipment Specification

Essentially, the equipment is composed of a line of pre-treatment and anodizing tanks. Operations and assemblies serving to carry them out are described in details in Table no. 15. The equipment is operated by three cranes of a handling capacity of 700 to 1000 kg each that can be positioned both horizontally and vertically.

Major units of the equipment are: 12 dc- and ac-sources, cooling devices, compressors, ventilating fans, a steam boiler. For their operation, applied power as detailed below must be provided:

Table 15 - Technological Equipment for the Anodizing Plant

Item	Operation	Rectifier, V/A	Operational temperature, approx. °C	Approx. volume of tank, litre	Inner width of the tank, mm	Material of tank	Inner lining	L-heating J-cooling	Autom.temp.control	Anode holder	Compressed air mixer	Rinsing sprayer	Heat insulation	Exhaustion duct, thousand m^3/h
01-03	Racking													
04	Degreasing		80-90	13300	1000	F	K	L	X		X	X	X	12
05	Rinsing			10640	800	F	G				X			
06	Frame etching		70	10640	800	F	G	L	X		X		X	15
07-08	Satination		55	21280	1600	F	G	L	X		X		X	30
09	Rinsing			10640	800	F	G				X	X		
10	Rinsing			10640	800	F	G				X			
11	Desmutting			10640	800	R	-				X			
12	Rinsing			10640	800	R	-				X	X		
13	Rinsing			10640	800	R	-				X			
14	Anodizing	25/8000	20±1,5	18620	1400	F	K	J	X	X	X			14
15	"	"	"	31920	2400	F	K	J	X	X	X			27
16	"	"	"			F	K			X	X			
17	"	"	"	31920	2400	F	K	J	X	X	X			27
18	"	"	"			F	K			X	X			
19	Rinsing			10640	800	F	G					X		
20	Rinsing			10640	800	F	G							
21	Colouring	30/4000^x	20-25	15960	1200	F	G			X	X			
22	"	"	"	15960	1200	F	G			X	X			
23	Rinsing			10640	800	F	G				X	X		
24	Rinsing			10640	800	F	G				X			
25	Sealing		95-100	31920	2400	R	-	L	X					
26	Sealing					R	-	L	X				X	
27	Sealing		95-100	31920	2400	R		L	X					
28	Sealing					R		L	X					
29	Sealing		95-100	31920	2400	R	-	L	X					
30	Sealing					R	-	L	X					
31	Drying													
32	Drying													
33	Unracking													
34	Unracking													

Legends:	Material of tank	Inner lining
	F - steel	K - hard rubber, 4 mm
	R - stainless steel	G - hard rubber, 2 mm

Note: ^{x} ac

- electric power: 1600 kVA, 3x380 V 50 Hz, cos φ = 0,9 max., starting output 1350 kVA max.
- steam for heating: 2700 kg/h, 2,5 bar max
- compressed air: 1900 m^3/h, 400 mbar
  40 m^3/h, 4-6 bar
- air exhaustion: 125 000 m^3/h

To complete the plant, appropriate recipient and storage tanks for chemicals, delivering pumps as well as pipeducts and electric lines must be installed.

Facilities serving for fresh water treatment and sewage treatment are discussed with price indication in Chapter 5.

The following prices based on 1983 prices, spare part supply for one year included, (FOB port of the continent where shipped) may be taken into account (for information only):

	(thousand U.S.$)
- automatic anodizing line (capacity 3000 tpy)	1600
- auxiliary facilities, tanks	450
- engineering, know-how	170
Total:	2240
- installation, commissioning, installation management and training of operators by the supplier included	550 thousand U.S.$
- Plant hall with cranes and sanitary engineering systems	250-350 $/$m^2$

Note - The chemicals required for the first filling-up and a four-weeks test run should be taken into account as demand for working capital.

Some firms which may be taken into consideration as technical designers or suppliers of know-how and engineering as well as installation organizators:

GALVATEK OY	Finland
ALUTERV-FKI	Hungary
BLASBERG	F.R.G.
FEAL	Italy
CEGEDUR-PECHINEY	France

Staff requirement for operating the equipment:

	person/shift
- racking	6-8
- unracking	4-6
- process technician	1
- maintenance	1
- quality controller	1
- group leader	1

When operated in three shifts, the plant requires a staff of 43 to 55 percons, one foreman included.

3.2.3 - How to Ensure Quality

The semi-finished good as extruded is to be considered as preliminary product to be anodized. Its chemical composition, metallurgical and surface quality determine whether the given lot is capable to meet the requirements set for the actual technological variant. In addition to the well-known methods of chemical, mechanical and metallurgical nature, test anodizing is the most reliable practical procedure of quality control. It is important to keep the variations in chemical composition of extrusions, their mechanical properties and structural characteristics within strict tolerance limits. If experience proves that the supplied or produced profiles are of a constantly good quality, the coverage of tests may be reduced. As a precondition for it, technological specifications valid for the billet foundry and extrusion plant must be kept in the strictest way.

Adequate quality of technology means to form an oxide layer on the surface of aluminium, by carrying out various operations of surface treatment in a defined order, applying or not applying current to pieces placed in solutions of different composition. The desired quality cannot be obtained unless the concentration of agents and impurities in each solution as well as temperature, agitation, parameters of current and duration of treatment are severely controlled and continuously corrected so as to keep them within specified limits. All these preconditions can the more properly be provided the higher is the degree of automation that the plant has attained. Manual racking, jigging to frames and unracking of anodized profiles are also of grat importance for their good and uniform quality.

When checking the quality of oxide coating, tests and inspections for
- attractive uniform appearance,
- thickness of coating,
- shade of colour
- efficiency of sealing

must be carried out. It is recommended to perform these tests in accordance with the provisions of international standards (ISO, for example) or standards valid for the territory where the products are to be sold. Some American standards which can also be referred to when qualification tests are carried out are listed below:
- ASTM B-487-79, ASTM-B-137-45 (rev.1979), ASTM B-244-79, ASTM B-580-79, ASTM-B-457 (in. rev.), ASTM B-368-68

(rev. 1978), ASTM D-658-70, ASTM D-523-67.

3.2.4 - Environmental Protection

Similarly to other technologies of chemical industry, the protection shall cover both the micro and the macro environment, i.e., ensure the undisturbedness of conditions on the work place itself as well as out of the plant's doors. As regards the work place, the possible causes of the workers' uneasy feeling should be eliminated and health protective measures such as noise protection, electric shock-proofness, etc., be taken, whilst to protect the macro environment, air and water contamination must be avoided first of all.

Main factors susceptible of contamining air are aerosols formed of vapours and gases released by alkaline and acidic technological solutions. For the micro environment, air change ensuring working conditions which are not harmful to health can be provided by a flange suction at the tanks and by an overall ventilation of the buildings. In order to avoid an atmospheric contamination, the exhausting system shall be equipped with adequate separators: spray catchers, scrubbers, etc.

Prevention of water contamination usually means a double task, i.e., that of neutralizing sewage, i.e., bringing it to a pH-7 value, and of keeping certain kations or anions below of a given concentration value, in sewage. For the purpose, ion-changing methods are mostly used, for, these special procedures are capable of separating impurities present in small concentration in rinse water even if large water volumes are concerned. The procedure concentrates the chemical impurities and allows the remainder rinse water to be geared back into a recirculat-

ing system.

Basically, measures serving to prevent accidents should be taken when designing and constructing the plant. By training the workers and prescribing the proper operations in the Working Instructions, accident prevention should be turned into an integral part of technology.

4 - HOW TO INCREASE THE EXTRUSIONS' DEGREE OF PROCESSING

As a general rule, a product is the more economical the more "soft ware" is contained therein; thus, a complex product of low material content, e.g. a foil coated with a photosensible layer, can be sold for a higher profit than a scarcely available basic material of high energy contents, e.g. pigs. In consequence of this fact and because of the increased competition among manufacturers of semi-finished products, namely extruders with one another, it is usual to strive for selling extruded products in a further processed state permitting their direct utilization, i.e., for increasing the sellers services.

It is anodizing of extruded products, first of all, profiles, which increases their corrosion-proofness and ensures their attractive and manifold appearances, that has kept spreading. There are also other methods which result in added value of extruded products than can be reflected in their price. A detailed discussion of these methods, procedures and operations is beyond the framework of this Study so much so that they are subject to steady changes, introduction of new ones, etc. Nevertheless, some of them are briefly described herebelow:

a) In addition to anodizing, various painting methods may also be used in order to obtain a wide diversity in the appearance of profiles.

b) Formation of profiles for thermal-break windows (first, the hollow is filled up with an insulant of low density and, then, the metal strip serving as "termal-bridge" is removed).

c) Development of profile families permitting the customer to vary the extrusions and obtain thus doors, windows separation walls, etc. of various sizes and design. Systems of the same type can be developed for shelves or other commodities.

d) Preparation of pieces from various profiles by surface treatment, appropriately bevelled cutting-up, boring of holes and threaded holes and appliances, such as fittings, door-handles, screws, joining elements, insulations, and their arrangement to packages allowing even an unskilled customer to assemble the desired object without using special devices on the field.

The most accepted finishing method, anodizing resulting in an increase of the degree of processing of the extrusions is discussed in Chapter 3.

The purpose, effect and, partially, implementation of profile painting is comparable to those of anodizing. Preparatory operations are practically identical but complemented by the formation of a thin oxide layer underneath the paint, not inevitably requiring the use of a current source. There are a number of painting variations known, and colouring procedures using carriers other than organic solvents and causing thus no environmental contamination have became popular nowadays. If an anodizing shop has already been installed in the factory, it can be complemented with a painting section for relatively low capital cost.

Filling of profiles with an insulating foam and removal of the "thermal-bridge" (forming of the "thermal break") may be carried out by means of a relatively simple single-purpose machine.

If the extrusion shop's staff is relatively unskilled in developing profile families permitting a large scale of up-to-date finished products to be designed, the shop should resort to purchasing know-how of firms enjoying reputation, together with the relevant tool constructions and production technology.

In order to produce profiles and fittings ready for assembling, completed in accordance with the customer's request, a number of machines are required:

- rotary disk saw equipped with a driven roller conveyor causing no damage to the surface of profiles as well as with positionable limit stops and a gauge beam; the angle of the cutting plane to the longitudinal axis of the table should be adjustable;
- simply re-adjustable drilling machine(s) provided with appropriate clamping fixtures;
- facilities servicing the above machines such as devices for saw disk edging, bit setters, etc.

It is to be noted that such a completion needs a relatively extended use of man-power.

Accessories of other than profile nature required for completion must either be purchased or produced inside the walls by means of smaller single-purpose machines. The production of such goods, e.g., aluminium screws, has, in addition to completing packages rady for assembling, a character of assortment extension and contributes to the increase of the specific profit of the entire factory.

It is very important to use a technology for all the operations of processing so as not to damage the surface quality of well extruded and anodized products in any way.

It should be kept in mind that orders for delivering "unit packages" composed of several profiles and accessories cannot be complied with unless manufacture is excellently organized. Otherwise, the time to be spent for completion would be extended resulting in important economical losses in consequence of growth in the stock of unfinished products, on the one hand, and a quality deterioration inevitably occurring during the days of waiting, on the other. Furthermore, it should also be considered that the clientele cannot be kept unless attended on in a reliable and quick manner.

5 - AUXILIARY PLANTS

5.1 Conceptual Description

5.1.1 - Power Supply and Public Utilities

The equipment used for carrying out manufacturing processes and other, auxiliary activities can be operated by supplying it with various kinds of energy. Provision of the required energy involves an important volume of both non-recurrent and recurrent expeditures.

Fields of power consumption directly for technological purposes are:

- billet production: melting, casting, homogenizing, etc.,
- extrusion: billet preheating, extrusion, finishing, heat treatment,
- surface treatment: anodizing, colouring, operation of water supplying, air-technical facilities, etc.

Types and utilization fields of indirect power consumption and supply are:

- heating of buildings, hot water supply for technological ang social purposes, lighting, etc.,
- compressed air supply for operating pneumatic systems of equipment,
- industrial water supply for cooling equipment and cast metal, producing electrolytes, potable water supply for social purposes,
- fuel supply for transportation and material handling,
- the consumption of servicing spheres: maintenance, laboratories, plant management, storage.

These requirements can be met by using electricity and natural gas in an optimum way as regards both manufacturing processes and the capital costs. The use of electricity and oil-firing is less favourable;

finally, the plant may totally be based upon electricity. If particular natural conditions prevail, exploitation of coal or a geothermic heat source may also be favourable. It should be noted that if the supply of natural gas is not quite reliable, possibility of a reserve energy agent use must also be provided e.g., using universal burners, etc. Recuperation of waste energy can also be advantageous, e.g., the heat conent of flue gases in melting furnaces can be utilized for water heating.

The problem of a continuous and safe energy supply must be settled. For those supplied for direct technological consumption through conduits or lines, such as electricity, natural gas, or suited for being stored, e.g., oil, coal, purchase is recommended. For those of indirect exploitation, the establishment of an own energy developing unit seems to be expedient; the demands for compressed air should also be satisfied by the extruder's own facilities. If adequate water reserves are available either on or under the ground surface, they should be exploited by own water works; if not, water must also be purchased. Considering the importand economic advantages involved, such as lower specific costs of establishment, operation, reduced demand for labour, it is highly advisable to share the sources of heat, industrial and potable water and compressed air with other producing plants, if not impeded by environmental conditions.

5.1.2 - Maintenance

A maintenance strategy should be laid down concurrently with the plant establishment, defining the relation between the cost of maintenance and safe production as well as the means, technology, staff and organization required for repairs. The appalication of planned preventive maintenance, together with the so-called "repair as needed" may be recommended for basic productive equipment; this, however, requires an appropriate technical-diagnostic system.

For new establishments and where the terms appointed by the authority for checking are fixed, e.g., in the case of hoisting engines, motor vehicles, etc., a time-dependent method of maintenance may also be prescribed.

The staff required for maintenance may decrease, depending upon the ratio of division of jobs between the inner and outdoor organization, within the range of 15 to 20 per cent of the entire staff of the plant, if provided external labour is available to cover 25 to 30 per cent of the whole maintenance activity.

Experience shows that the costs of maintenance amount to 5 to 7 per cent of the value of the total capital goods.

5.1.3 - Transport of Material

Material transport involves transportation and loading of materials as listed below:

- transportation of stacked pigs and master alloys to the casting shop from the store of basis material;
- transportation of scrap stored in covered cases from the extrusion plant, into the scrap storehouse and further to the casting shop;
- transportation of billets on the way between the casting shop and the extrusion plant, perhaps touching also the intermediate stores;
- conveying of extruded products stored in transportation

frames into the anodizing workshop or the store;
- shipping of finished products;
- handling of various auxiliary products, fittings, maintenance material.

5.1.4 - Packing of Extruded and Extruded/Anodized Products

Packing serves to keep the product in its original state as produced until delivered to the end user, i.e., to protect it from mechanical deformation or surface damage during transportation and reloading, as well as against corrosion and, in general, against any impairments.

A survey of the way of the product up to the customers should be made and, relying on its findings, the requirements the packing has to meet should be defined; however, the requirement of flexibility also suggests to hand over products to marketing enterprises in packing that contributes to their exportability. If a long way on sea or tropical weather conditions are to be expected, a hermetically sealed packing provided with a moisture absorbing cartridge may be necessary.

5.1.5 - Storage

In order to ensure the optimum quantities on stock of primary and auxiliary materials necessary to service the major technological processes in a trouble-free way, data related to both trade and infrastructure of the environment where the plant is to be established must be acquired.

Mechanization is recommended. In the case of finished goods directly sold from stock, a computer-controlled manipulator is proposed to be used for servicing the storage compartments of elevated storage-houses.

Trouble-free production shall be ensured by a planned storage of the following:

- basis material: pigs and master alloys,
- scrap from production,
- semi-finished products,
- finished products,
- packing material,
- tools,
- energy agents, fuel,
- spare parts, auxiliary material for maintenance,
- labour-safety devices and facilities.

5.1.6 - Sewage Treatment

Water can become contaminated, in consequence of either operational reasons or a trouble, during its utilization for technological or social nature.

After having been purified, water can be used again; contaminated water, however, that is no longer suited for being utilized shall adequately be caught together with precipitation water the volume of which depends upon environmental conditions.

Contamination level of water leaving the plant, i.e., the ratio of oil or chemical contents to the entire volume shall by no means be higher than provided by the actual requirements of environmental protection.

When designing the system that will serve to discharge and catch sewage, the investor shall take into consideration the quantity of impurities penetrating into the recirculation systems servicing the anodizing, billet casting and other equipment, furthermore, all the contaminations in water of single utilization purpose, e.g., washing and used for social purposes.

5.2 - Choice of Technology and Equipment

5.2.1 Power Supply and Public Utilities

The direct demand for power is a function of the product mix composition, the volume of production and the technological parameters. Table 16 states, based upon the major Variants of the establishment discussed herein, the power and services requirements for operations.

Direct consumption, in addition to the production itself, depends upon the size of premises, the weather conditions, the staff, the water supply feasibilities.

The data in the Table refer to the case where melting, apart from master alloy production, as well as ageing, homogenizing, billet preheating and heat treatment are performed in natural gas-fired furnaces, and natural gas is also used as combustible for obtaining thermal energy, and the demand for water is reduced by re-cooling in a re-circulation system so as to permit repeated utilization.

When summarizing the power demands, a coincidence factor of about 0,9 may be taken into account.

Considering the data of the Table 16 demands for power have been calculated for a factory comprising a foundry of 16,000 tpy capacity, an extrusion plant with two presses, an anodizing plant with a 3000 tpy output and all the required auxiliary shops:

Table 16 - Demands for power and services

Techno-logical Variants		Output	Electr. energy		Natural gas		Combustible		Water		Compr. air	
		$\frac{\text{ton}}{\text{year}}$	$\frac{\text{MWh}}{\text{year}}$	MW	$\frac{\text{MWh}}{\text{year}}$	MW	$\frac{\text{MWh}}{\text{year}}$	MW	$\frac{10^3 m^3}{\text{year}}$	$\frac{m^3}{h}$	$\frac{10^3 Nm^3}{\text{year}}$	$\frac{Nm^3}{h}$
Foundry		4000	600	0,2	8000	2,6	900	0,5	240	120	120	30
		8000	1040	0,3	15200	4,8	1350	0,7	440	220	200	50
		16000	1760	0,6	36800	13	1800	1,0	1200	600	350	80
Extrusion plant	A	5000	4000	1,3	3500	1,8	1800	1,0	50	16	70	16
	A	6500	4500	1,5	3900	2,0	1800	1,0	100	30	80	17
	A	13000	9800	2,4	6500	2,8	3600	2,0	190	60	130	35
	B	13000	10500	2,5	7800	3,3	3600	2,0	190	60	140	35
Anodizing plant		3000	7200	1,5	-	-	10000	2,5	60	15	1400	300
		6000	14000	3,0	-	-	16000	3,5	120	30	2100	450
Storage		-	300	0,1	-	-	1000	0,5	10	4	10	3
Water supply		-	300	0,1	-	-	100	0,1	-	-	-	-
Compressed air		-	250	0,05	-	-	100	0,1	10	2	-	-
Steam generation		-	100	0,04	-	-	-	-	30	10	-	-
Other		-	800	0,3	-	-	2000	1,0	50	15	5	2

	Power	Utilization a year
Electric energy	4 MW	2210 MWh
Natural gas	20 MW (2000 Nm^3/h)	63.200 MWh ($6,3.10^6$ Nm^3)
Water	650 m^3/h	1550.10^3 m^3
Compressed air	400 Nm^3/h	1905.10^3 Nm^3

Major characteristics of power supplying systems can be summed up as follows:

Electric power supply

It is expedient to couple the factory to a medium voltage public supply network and to transfer untransformed power through cables to the most important consumer plants or equipment from the central reception station.

When local conditions require, the installation of a main transformer stepping down voltage of 35 to 100 kV tapped from the transmission line to a medium voltage range of 3 to 10 kV may be necessary.

Operational distributors and individual facilities located in the halls are supplied by transformer stations for medium/low voltage. Medium voltage should be equal to the operational voltage of units to be supplied with medium voltage, if any; the unit output of the transformers should be adapted to the highest installed consumer's applied power. It is recommended to install a transformer park composed of interchangeable units. For electrical heating or heat treating furnaces, air insulated transformers of 1 to 1,6 kVA capacity designed for indoors service should be used; otherwise, a capacity of

0,63 to 1 MVA will suffice. An adequate value of phase factor should be provided by installing automatically switched capacitor banks on the low voltage side of the transformers.

Operational safety considerations suggest to use an insulated medium voltage network, while low voltage systems may be provided with a protective neutral (fourth) wire.

It should be kept in mind that rectifiers used in the anodizing plant cause undesired distortions on the mains.

Plants servicing large areas require a reinforced power input, a double reserve may also be justified for various equipment such as water intake, compressors delivering compressed air, boiler shop, overall lighting.

In order to avoid problems arising from voltage fluctuation and/or short circuits, the paramters of the electric power supply plant shall be controlled carefully.

Natural gas supply

The center of natural gas supply is the station of the factory's attachment to the outer network where the pressure of gas is reduced. Thus natural gas is supplied to the burners at a pressure of 1 to 2 bar; there, a local pressure regulator provides for stabilizing the desired pressure level.

The pipeduct network and the burners and/or their surrounding shall be equipped with sensors detecting accidental gas escapes. If the gas supply is susceptible of intermittence, adequate reserves of combustible oil should be provided; there are burner combinations permitting oil to be substituted for gas, if necessary.

If the plant's power supply is based upon combustible oil, an area appropriate for racking and stocking oil should be provided, taking into account the fire risk involved, and, therefrom, oil should be adducted to the consumers through a pipeduct system.

Supply of heat for heating and hot water for social purposes

Climate conditions may require a considerable thermic energy consumption for heating purposes. A central boiler plant fired with natural gas, oil or coal can be installed producing steam of 4 to 10 bar or hot water for the heating of the buildings. The condense system for steam should be designed in conformity with the heating system of the buildings.

Water heating for sanitary purposes may be carried out by using adequate equipment settled either centrally or in a decentralized way at the utilization points.

In addition to instruments and control serving for operation and safety, the steam generator or heat supply equipment must be provided with quantity measuring devices for control and saving purposes.

Compressed air supply

Compressed air of a pressure of 4 to 6 bar required by the technological plants should be generated in a central engine compartment; air cooling, purifying and storing units should also be located therein. With a view to generate reserves, the compressor compartment of relatively low delivery should be composed of several units. Compressed air is transferred to the points of utilization by pipeducts. Within the halls, plants, etc., distribution is made by means of web ducts and joining branch pipes. It is advisable to check the volume of generated and utilized air by proper measurements.

Water supply

Water to be utilized for production purposes must meet various requirements of quantity and quality. The highest consumption of water is in the foundry to obtain an adequate solidification of molten metal; 3-5 NK^o water of 18 to 25 ^oC temperature and 4 to 6 bar pressure is required.

A considerable volume of water is needed for cooling of the parts and bearings of machines operated in hot environment, hydraulic fluids, etc.; in addition to the above parameters, an absolute purity is also required in this case since a minimum of contamination (by oil, for example) is susceptible of deteriorating heat transfer capacity.

An important volume of water is needed for electrolytes in the anodizing plant requiring a particularly careful treatment because of its chemical impurities. This water may be also used for supplying boilers.

Finally, the necessity of establishing a special plant for meeting the demand for potable water supplying for social purposes may also arise.

If an abundant water source is available, the demands can be met even by utilizing water only once. If the factory can be joined to a water supply utility network, distributor conducts must only be laid. However, if water reserves are available either on or under the ground surface, a constant level of water pressure must be ensured by means of water raising and booster pumping plants, water tower, if possible.

In areas poor in water, the equipment may be cooled by a closed recirculation system: heated water re-cooled in cooling towers to 20-25 °C must be recirculated by pumps. If the system is properly closed, fresh water volume necessary for replacing evaporation and leakage losses may be as low as only 10 % of the whole demand.

Depending upon the reserve water's quality, softening or even a special water tratment may be required. When industrial water is used for several various purposes, considering the divergence of quality requirements, installation of self-contained recirculating systems separated from one another may be justified. It is highly recommended to set up a separate system for cooling the moulds of casting machines; all the other consumers may be attached to a common system. When producing potable water locally, all the relevant sanitary regulations shall be kept rigorously. The use of a water tower is also advantageous when circulation water supply is installed; in such a case, a storage capacity corresponging to a demand of 1 to 2 days should be envisaged, taking into account the provisions concerning fire protection and returned to the tower by gravitation or by means of pumps.

The pumps serving for water supply should be located near the cooler and the water tower and/or the central storage reservoirs.

With a view to water saving purposes, the water system shall be equipped with instruments measuring volume and technical parameters.

General layout of power supply and utility establishments. Capital expenditure

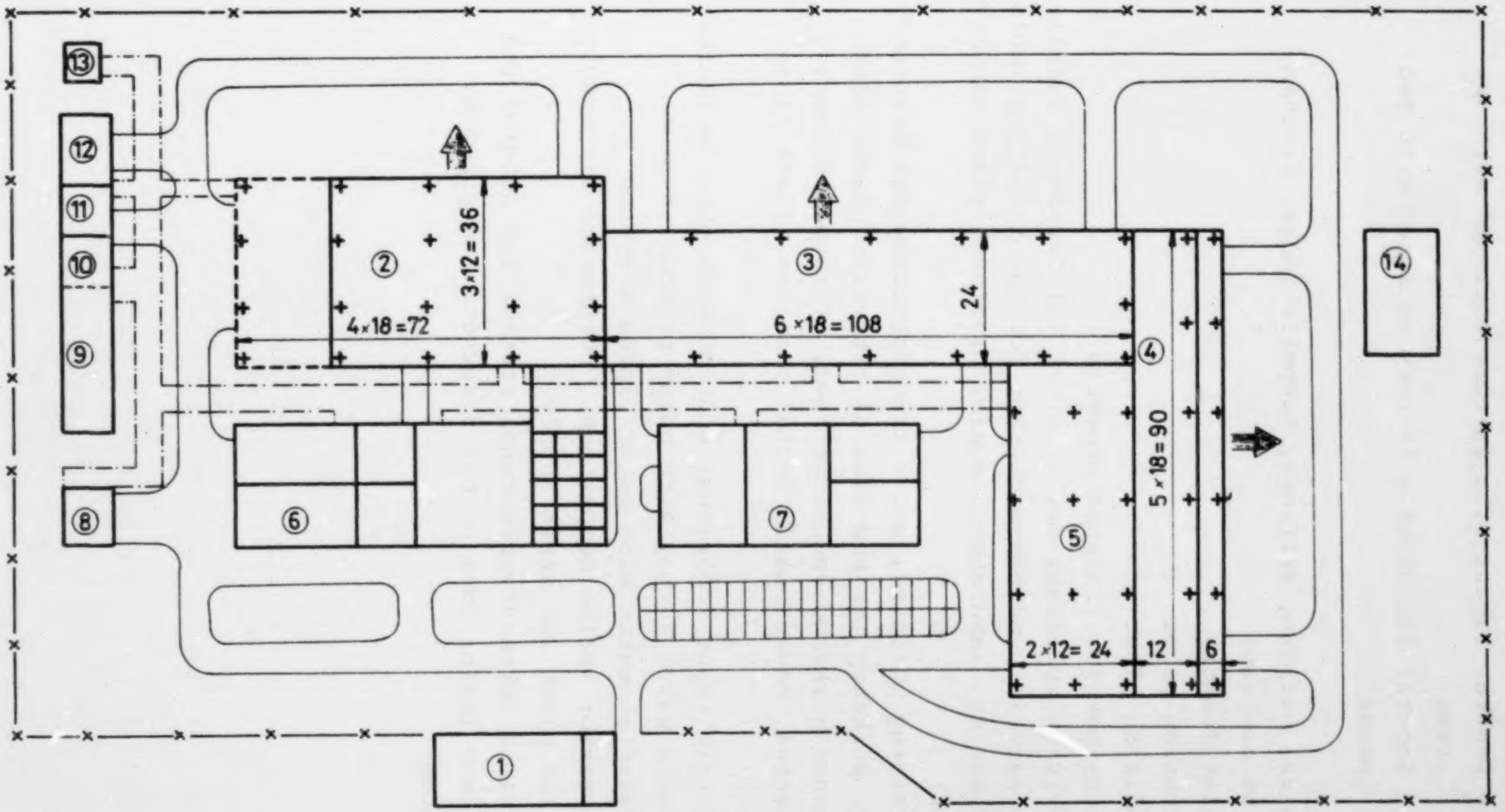
A recommended general layout and arrangement of power supply and utility establishments is shown in Fig.s 12 and 13.

Apart from the cable network for electricity, all the web ducts servicing the plants should be located overground on a tubular bridge. Adequate lightning protection, insulation and feasibility of repair shall be provided.

Table 17 contains a list of establishments of power supply and public utilities together with the major technical parameters and estimated capital costs. By organizing a central despatcher service, the staff concurrently present in the plants can be reduced.

5.2.2 - Maintenance

Item of the equipment which require a regular maintenance are listed below:
- systems of the hydraulics: presses, etc.,
- furnaces and their servicing equipment: melting, casting, heat treating furnaces,
- finishing machinery: finishing lines, saws, packaging machines, etc.,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4×18=72
3×12=36
6×18=108
24
5×18=90
2×12=24
12
6

M1:1000

Fig.12 General layout of a factory equipped with one press

Fig. 12 - General layout of a factory equipped with one press

Fig. 13 - General layout of a factory equipped with two press

1 - Central building (offices, keeper's lodge, kitchen, works canteen)

2 - Billet foundry

3 - Extrusion plant

4 - Anodizing plant

5 - Store-room for finished products

6 - Servicing building, no. 1 (store for foundry's auxiliary material, maintenance shop for the foundry's tools and moulds, laboratory, social premises, plant management)

7 - Servicing building, no. 2 (manufacturing and maintenance workshop for the dies of extrusion plant, maintenance workshop and store-room, storage for packing material, occasionally social premises, plant management)

8 - Electric input (coupling) station with outer networks

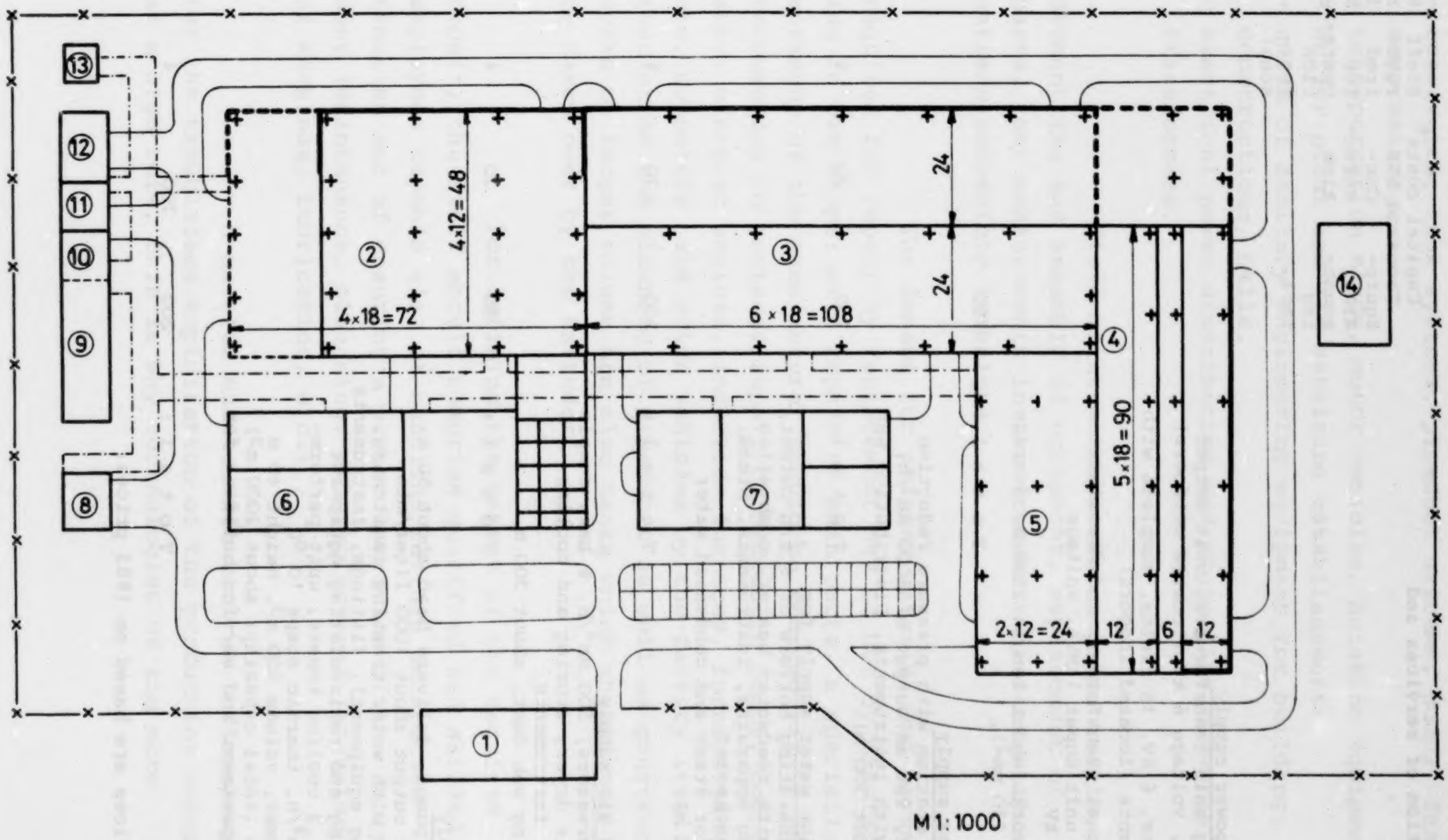
9 - Potable water supply with outer pipeduct system

10 - Industrial water with outer pipeduct system

11 - Compressor engine compartment, compressed air supply

12 - Boiler plant and steam supply

13 - Coupling (pressure reducing) station for natural gas and web (main) duct or oil reservoir and pipeduct system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4×18=72
4×12=48
6×18=108
24
24
5×18=90
2×12=24
12
6
12
M1:1000

Fig. 13 General layout of a factory equipped with two presses

Table 17 - List of power supply and public utility establishments

Specification of services and equipment	Capital costs[x] Thousand US$		Staff required for operation (persons)	Space requirement, m^2
	Equipment, mounting incl.	Construction		
Electric power supply				
2 coupling main transformers, unit output 6,3 MVA, voltage 6 kV (located outdoors)				
distributor, 6 kV, 15 fields, complete with instruments (located indoors)				
8 operational transformers and distribution system, unit ouput 1 MVA, voltage 6,3/0,4 kV				
Cable network (about length 2500 m, average section 120 mm^2),				
Total:	350	70	4	100
Natural gas supply				
Reception station with pressure reduction of 6/2 bar, for an output of 3000 Nm^3/h, complete with instruments. Distribution web ducts (about 300 m)				
Total:	100	20	4	50
Heating, hot water supply for				
2 steam generating boilers of 6 t/h output, complete with feedwater heater, combustion air feeding apparatus, instruments. Steam: 6 bar, superheated				
web duct for steam and condensed water (about 800 m)				
Total:	250	70	4	150
Compressed air supply				
2 air compressors, 500 Nm^3/h, 6 bar, complete with air dryer, storing and cooling equipment, instruments				
distributing web duct, about 300 m				
Total:	80	30	4	80
Water supply				
8 booster pumps, delivery head about 50 m, delivery output about 1000 liter/min Complete with water treating (softening, purifying equipment), fittings, instruments				
Distributing and recirculating equipment				
Buildings: 2 cooling towers, unit performance 200 m^3/h, thermic steps 10 °C				
1 water tower, volume 500 m^3, height 40 m				
Reservoirs (total capacity: about 2000 m^3)				
Engine compartment and service building for pumps				
Total:	200	700	4	400

Note: [x] Prices are based on 1983 prices.

- reservoirs, tank systems, pipeduct systems, pumps, fans, compressors,
- transportation means, motor vehicles, hoisting equipment,
- boiler plant and its servicing establishements,
- units of sanitary engineering equipment for building, constructions, halls,
- electrical power distributing and signalling networks, transformers.

Field maintenance works comprise testing, dismantling and assembly of equipment, replacement of parts, test measurements in the framework of warrantly obligations and safety technique.

The demand for simpler material and parts required for repair by replacement may be met by manufacturing in own shops; with repair of main parts, a specialized workshop or the manufacturer should be charged. It is not recommended to envisage rapair of hydraulic pumps, compressors, electric engines, induction furnaces, furnace jackets, computers and motor vehicles by the factory itself. Insulation and cleaning of pipeducts as well as construction works of larger volume are also tasks which should not be taken over by the extruder.

For defining the extent of the required repair, the staff should comprise qualified and skilled employees capable also of handling certain unexpected troubles and of ensuring a proper operation of the equipment (maintenance, cleansing, oil replacement, adjustments of machines, lubrication, etc.) .

A careful maintenance work is indispensable for the troubleless exploitation of the production means at a high rate, this is why technologies of the more complex repair operations should be worked out and, at the same time, severe labour protective provisions must also be complied with.

Recommended composition of the maintenance staff by profession:

- 70 % mechanical technicians (qualified workers skilled in machining, locksmithery),
- 25 % electrical technicians (electric fitters, locksmiths, electronical technicians),
- 5 % building maintenance men.

The work of the maintenance staff should be managed centrally; the same holds for the preparation and manufacture of spare parts.

For the central repair shop, a specific surface area of 3 to 5 m^2/worker should be calculated. Metal cutting machines should be installed in this shop.

Among those charged with technical management, an adequate number of employees are also required for spare parts provision, designing of smaller modifications, care of documentation, etc.

The base facilities, tools and means as listed below should also be provided:

For mechanical works:

- gaswelding and electric welding machines,
- metal cutting machines (lathe, universal miller, horizontal drilling mill),
- universal grinders,
- heat treating furnace for spare parts manufacturing,
- pipe bending, cutting machines, saws,

- consumption adjusting instrument for motor vehicles,
- machine for applying furnace insulation material,
- oil separator, oil filter carriage.

For electrical works:
- base instruments (ammeter, voltmeter, insulation resistance meter)
- portable balancing equipment and vibrometer
- line trajectory searcher, trouble indicator
- testing and programming apparatus for units equipped with microprocessors.

Capital costs of establishing a machinery comprising units of the above function amount to about U.S. $ 200,000,-

5.2.3 - Transport of Material

Raw materials arrive at the factory in a piled-up state and are transported to the store by a fork lift trucks.

Logs may be moved in handling frames, while cut-up extruded billets in carts. Fork lift trucks and/or overhead cranes may also be used for the purpose.

For transporting waste material, chips, scraps, cut-up extremities, etc., arising in the foundry and extrusion plant, cases are used. The cases are designed in such a way as to permit waste material to be directly loaded into the furnace therefrom by a charger. For material transport between the extrusion plant and anodizing shop, as well as between the anodizing shop or extrusion plant and store-room for finished products, handling racks are used which also serve for material handling within the extrusion plant itself.

For a fully developed factory, the following items are required for a troubleless performance of material transportation from one plant to another:

- four way storage truck, 2 t		2	pcs
- front fork lift truck, 2,5 to 3 t		5	"
- platform truck, 2 t		2	"
- side fork truck, 2,5 to 3 t		2	"
- handling frames and carts for extruded billets	about	100	"
- handling racks for extruded goods	"	120	"
- collecting cases for scrap	"	150	"

The capital requirements for transporting vehicle stock amounts to about 3 to 5 % of the total.

5.2.4 - Packing of Extruded and Extruded/Anodized Products

It is advisable to establish a packing system equipped with packing machines capable of applying packings which are suited for maritime transport but are not airproof. Subsequently, however, this system can be completed by facilities producing hermetically sealed packing.

The packing operations which have to be carried out on the platform forming part of the weigh bridge are as follows:

- A case of appropriate size is placed onto the weigher and strips of plastic band allowing the package to be lifted off as well as paper or plastic foil are put in its inside.
- The tare weight is read off.
- The extruded good is placed in the case by hand. Prior to that, the products are wrapped with special paper or

plastic foil either individually or by clasping several extrusions.

- After having been placed in the case, the extruded goods are covered with the inner packing material by folding it over, then, an interior strapping is made. Finally, the case is closed and strapped with steel bands.
- The completed package should be weighed in such a way that the weigher prints the major data onto a paper sheet which can be fastened on the case.
- The completed package should be transported to the storage and either prepared for shipping or transiently stored.

Package sizes that can be considered are as follows:

- length of the extruded product	2000 to 6000 mm
- cross section of the package	min. 200 x 200 mm, max. 500 x 500 mm
- weight of the package	min. 200 kg, max. 1500 kg, average: 450 kg

When packing anodized products, care should be taken of cleansing of the equipment since soft, not-anodized products are susceptible of causing stuck aluminium stains on the surface of roller conveyors and other equipment. Since the surfaces of anodized products are hard, on the other hand, the risk of damage is considerably lower.

If it seems justified, simpler methods of packing the profiles may also be used. Such packing is required for tubes, rods, wires.

Capital costs for a packing system comprising two packing stations, a bandaging device, a strapping machine, two electronic balances, roller conveyors and package transporting machine amount to about U.S.$ 120,000, foundation works and installation included. The required area, together with that for servicing, is 5x25 = 125 m^2.

5.2.5 - Storage

Storage of raw materials

The received pigs and master alloy pieces are piled and bundled; the unit weight of a bundle is about 900 kg. The bundles are stored at two levels one upon another.

Scrap is stored in chests piled on one upon another at three levels. The unit weight of the chest's content is about 400 kg. For the purpose, a covered area having a direct communication with the melting department of the foundry with a surfacing of 3 t/m^2 load capacity should be provided. A trunk within the factory should serve for communication.

Front fork lift trucks of 2 t load capacity with a Diesel engine serve for material handling.

Storage of finished goods

Finished products packed for shipping in self-containing packages, bundles or chests are stored in cantilever shelves open on one side. The height division of storage cantilevers should be changeable in accordance with the package sizes occurring the most frequently. The length of packages may not be longer than 6 m. When the packages are stored at 7 levels, and an average bundle's dimensions are 350x350x400 mm with a weight of 350 kg, the specific load of storage area makes 120 kg/m^2.

A storage building for finished products having a direct communication with both the anodizing plant and the extrusion shop is required. Its useful inner height should not be less than 6,5 m.

Four-way fork lift truck of 2 t load capacity should be used for transporting material to the store -200 m and to load transportation vehicles as well.

Intermediary storage of semi-finished goods.

It is recommended to establish intermediary stores. These intermediary stores should be capable of keeping a volume of products equalling to a 5 to 10 days output of the relative plant:

- for billets, the storage area may be located even outdoors at the communication point of the foundry and the extrusion plant, while
- for extruded profiles, it should be set up within the walls, at the communication point of the extrusion shop and anodizing plant.

Storage of other material

- Auxiliaries and utensils as well as refractory material for the foundry should be stocked in water-tight store-rooms near the main plants, the types of material being separated from one another.
- For storage of new and repaired dies, a shelf system should be installed in a separate store-room protected against dust, moisture and other harmful effects.
- Caustic and toxic chemicals should be stored within the borders of the water sewage treatment area of the anodizing shop. Other chemicals should be kept in separate store-rooms. The storages should be provided with means for pouring and tacking.

- Materials for running maintenance and servicing as well as spare parts should be stored in centralized storages.
- For stacking package material, an adequate place should be kept within the building which serves for packaging and storage of finished goods.
- For oil-based combustibles, a central oil reservoir should be provided at a place easy of access where racking can also be performed. Considering both fire protection and heat insulation aspects, it is advisable to locate it under the ground level.

5.2.6 - Sewage Treatment

All the types of water carrying a characteristic contamination shall be properly treated prior to being emitted, i.e., the contamination shall be diluted to harmless concentration.

The technology of sealing and colouring applied in the anodizing plant requires the use of ion--free water. Rinse water shall be salt-free, while water serving for previous rinsing shall have the characteristics of potable water.

The treatment of emitted sewage covers neutralization, separation of solid precipitates and control of salt content concentration. For the latter operation, a dilution by adding water serving for cooling the equipment or communal water is adequate.

Closed recirculation systems serving for cooling the equipment only exceptionally contain impurities.

As far as possible, communal sewage should be introduced into the sewerage system.

From a technical point of view, water and sewage treatment in the anodizing plant mean the most complex one of all such tasks. All the facilities required for the purpose should be set up in the building of the anodizing plant itself. The operations cover preparation of water of the quality required by the technological demands (desalinizing, ion change, filtration, etc.) and a treatment indispensable for sewage outlet (slurry de-hydration, neutralization, etc.).

Supposing that the capacity of the anodizing plant is 3000 tpy, capital costs for all these establishments will amount to about U.S. $ 500,000, depending upon the technical solution applied. The facilities are usually delivered by the supplier of the technological equipment.

A sewerage system serves for collecting sewage outlets of various origin; the same may be utilized to drain rain and underground water.

The quality of effluent water shall continuously be controlled in order to prevent contaminations, such as oil or chemicals, of high concentration arising from operating troubles from getting into the environment.

6 - MANAGEMENT OF THE PLANT. ORGANIZATION

When fully developed (Variant 2 b for the extrusion plant and the foundry and 6000 tpy for the anodizing plant), the factory requires the following staff to be employed:

- extrusion plant:	91 persons
- die shop:	20 "
- foundry:	93 "
- anodizing plant:	97 "
- power supplies:	14 "
- maintenance:	60 "
- packing, shipping, storage:	30 "
- technology, quality control:	30 "
- management, administration:	70 "
	505 persons

The above staff should be increased by 15 per cent considering those on sick-leave and holidays; that is, a staff of 580 persons can be taken as justified.

The product quantity envisaged to be marketed by the factory is about 11,500 ton a year, the supposed composition by product types, and the average selling prices (U.S. $/ton by the end of 1983) are, as follows:

- 3000 t profiles with a surface as extruded (av. pr. 2220 $/t),
- 2500 t profiles of medium and high strength quenched at the furnace, as well as drawn tubes, rods and wires (av. pr.: 2700 $/t),
- 3600 t anodized profiles, colourless (av. pr.: 2450 $/t),
- 2400 t coloured anodized profiles (av. pr.: 2800 $/t)

The value of the factory's planned annual production amounts to U.S. $ 28 350,000 and the average price income is 2517 $/t.

With the given staff as well as the volume and composition of output, the above factory may be considered as an enterprise of medium size.

The factory's productive plants, i.e., the extrusion plant, the foundry and the anodizing plant are operated in three-shifts. The other ones are charged with servicing the productive shops and are operated in one-shift order except for the all-day inspection service, tool shop and packing department being also on three-shift operation. As far as possible, repairs should be carried out on holidays.

There are two further departments deserving attention for the outstanding significance of their activity, namely, the technology development organization and the marketing department.

The standard of a product ready for being marketed and the expenditures incurred during its production are results of the entire factory's activity. The individual technological operations have to be correct not only by themselves but must serve for attaining the ends also as a coherent system. It should be noted, however, that as a general practice, the suppliers of machinery transfer only the know-how related to their own products.

Although the office or institute preparing the general outline of the factory works out the principal conditions of operation, there are several problems which cannot be solved by it. Thus,

- there are a number of minor details of technology that

cannot be considered even by the most careful designer;
- the actual demand for products on the market will be considerably divergent from that as forecast even if the most careful sizing-up has been made, particularly when a long period of time must be spent on the project implementation;
- the demands on the market will be subject to a continuous change as regards both the assortment and quality of products, the requirements increase steadily;
- a reduction of prime costs will be indispensable requiring a permanent development and intensification of technology.

An efficient technological (metallurgical) unit of the manufacturer's own should be set up in order to meet challenges of the above nature. It is recommended to incorporate within this unit - in addition to the technological service in the strictest sense - the quality control inspection together with its laboratories. The main testing facilities required for a smooth operation of the plants, are the following: a quantometer (automatic multi-channel spectrometer) for a quick analysis of alloys and other materials, a small chemical laboratory of traditional nature for testing master alloys, solutions and sewage, a mechanical testing laboratory with one or two tensile test machines for testing mechanical properties of extruded products, a laboratory comprising some small tanks for surface treating where test anodizing has to be carried out.

When an entirely new factory is being established, the necessary knowledge will certainly be missing during at least the first period of time. The manufacturer is suggested to have recourse to another factory within the country or skilled organizations abroad. Essential decision in this respect shall be taken concurrently with the investment project itself and care shall be taken so as to ensure availability of financial resources and personnel needed for its realization.

Purchase of know-how from such a factory does not mean a non-recurrent relation but a procedure of several years covering:

- transfer of the technologies used in another factory of similar level for the newly established one,
- training of engineers, foremen and skilled workers employed by the new manufacturer in the premises of the factory passing on its experiences,
- a co-operation through the seller's experts transmitting knowledge to and training employees of the purchaser in the field during the initial period,
- maintenance of regular contacts between seller and purchaser and a constant rendering of help in order to facilitate the adaptation of knowledge.

The value of such a transfer of experiences can be estimated in a rough way only; supposing the above coverage and the case of a factory of size and product assortment as described herein, it might amount to about 5 per cent of the gross production value.

Of course, in addition to purchasing know-how, all the training opportunities offered by the equipment supplier in relation to operation and maintenance shall be made use of.

Marketing is another activity worth of particular attention. It should be kept in mind

- That, especially in the phase of developing aluminium industry, the increase in the demands of the inland market will certainly fall behind the rate of growing of the industry's productive capacity. In order to find new spheres of utilization and reinforce the market relations already existing, it is recommended to set up, at the time of starting with the factory's operation, an organization charged with keeping connections with consumers.

- That the practices prevailing and demands emerging on the home and export market which can rationally be taken into account should be gauged. Relying upon the result thus obtained, the manufacturer should strive for delivering e.g., all the profiles required for a given system of windows and doors for a building, and should design, in co-operation with the consumer, new constructions which are suited for meeting the requirements more exactly. It could turn out, for instance, that the design and licence for manufacturing some door-window systems would prove to be worthy of being purchased already in the initial time.

7 - GUIDE FOR TAKING DECISION ON INVESTMENT

An expedient variant of the factory's settlement is illustrated in each of Figures 12 and 13.

Figure 12 shows the layout of an intermediary phase which, however, might be a variant of full development (Variants 1a/1 or 1a/2): the extrusion plant is equipped with one press, the foundry's billet production capacity amounts to 8000 ton a year and the anodizing plant's annual capacity does also not exceed 3000 ton. In all three of the plants, there is sufficient free area for an extension when the increase in the demand requires such adaptation. The auxiliary establishments must also be capable of being amplified.

Figure 13 is related to the phase of full development, the most variable and most generalized assortment (Variant 2 b). The same arrangement holds for Variant 2 a, too, with the exception that cold working equipment and heat treatment furnaces are omitted. If required, all three of the major producing plants can be amplified. With this arrangement, a rational and loop-less material flow - from the receipt of raw material up to the finished good's shipment - is possible.

Direct capital costs as necessary for the case of several Variants are summarized in Table 18. As regards the data in this Table, it is to be noted that as opposed to values ranged between a lower and upper limit as indicated in former Sections, the Table shows their arithmetical average value. Capital costs indicated for items 4 to 9 of the Table are indispensable and practically unchanged for any Variant of the productive plants; the degree of their exploitation may change, however. As an

Table 18 - Direct capital costs

Thousand US$

No.	Establishment	Variant	Construction	Machinery, equipment	Installation	Other expenses	Total
1.	Extrusion plant	1a/1	900	3070	510	300	4780
		1a/2	900	2350	470	300	4020
		2a	1800	5550	1090	500	8940
		2b	2300	11430	2050	600	16380
2.	Foundry	4000 tpy	880	1650	300	300	3130
		8000 tpy	1350	2840	560	400	5150
		16000 tpy	1900	6250	1200	600	9950
3.	Anodizing plant	3000 tpy	360	2070	550	170	3150
		6000 tpy	600	4140	1000	200	5940
4.	Die workshop		110	760	150	10	1030
5.	Maintenance		90	200	40	10	340
6.	Power supply, sewage treatment		1090	1470	200	100	2860
7.	Material handling		-	520	-	150	670
8.	Store-room for finished goods with packing shop		330	150	20	40	540
9.	Central and social establishments, roads, keeper's lodge, etc.		840	300	20	80	1240

exception, sewage treatment in the anodizing plant may be mentioned.

By the help of these data, certain conclusions can be drawn. For a preliminary evaluation, the index of phase income (margin) projected to every dollar of direct investment is rather suggestive. Phase income means the difference of selling prices and prices of aluminium material purchased for production pruposes.

It seems expedient to take, as basis for every Variant, an annual production amounting to 11,500 t; the product mix and mode of furnishing the base products may be different. Prices allowing a preliminary evaluation to be made are to be found in the Preface and Chapter 6, while data needed for an overall evaluation are summarized in Table 19.

Table 19 - Phase income attainable by a unit investment

No	Variant			Direct investment	Price income	Expenses for metal	Phase income	Phase income / capital cost
	Foundry	Extrusion plant	Anodizing plant					
	tpy		tpy	Thousand			US $	$/$
1	16000	2b	6000	38950	28950	18207	10743	0,276
2	16000	2a	6000	28560	27750	18207	9543	0,334
3	16000	2b	-	32030	26730	18207	8523	0,266
4	8000	2a	6000	26710	27750	18584	9166	0,330

Using the data in this Table, the following statements can be made:

- the Variant no. 2 ensures the highest phase income per unit of direct investment;
- the Variant no. 4, while resulting in a nearly similar

phase income, requires the lowest investment cost; the most important characteristic of this Variant is the fact that the factory meets 50 per cent of its demand for billets by purchase and its own foundry is not developed to an extent larger than required for processing its own scrap with added pigs;
- anodizing exerts a favourable influence on the specific phase income by increasing price income at a rate higher than that of investment costs;
- because of the high capital expenditures, it is Variant no.1 that yields the relatively lowest specific phase income.

Of course, the analysis of specific phase incomes serves for helping orientation only and cannot form, in itself, an incontestable basis of decision. First of all, the product prices serving as basis show a high rate of change. Irrespective of whether an assortment seems to be advantageous, the factory should manufacture products actually demanded by and vendible on the market.

During the initial development phase of the industry producing and using semi-finished aluminium products, factories offering a larger product scale will have a better start owing to their production and marketing flexibility. Therefore, it is probably Variant no. 1 the establishment of which should be insisted upon, if the extrusion plant in question were the first one to be set up in the country. It is also important to strive for a full exploitation of the capacity of the relatively expensive heat treating and drawing equipment, i.e., to give preference to the production of cold worked and heat treated goods to that of cheaper untreated ones since the specific phase income can thus be increased.

The development trend of the primary costs can be forecast by means of a simplified method.

For the analysis, prices of 1983 discussed above may serve as basis. It is to be noted that capital costs do not include any expenditure for infrastructural investment outdoors and do not take into account expenses arising from the utilization of the plant area.

When calculating the cost items, the method below should be used (Variant no. 1 in Table 19 shall be taken as a general basis):

- Aluminium raw material from an inland source, considering a melting loss of 2 % : 1583 $/t
- Power according to Table 16, taking into account a unit price of 15 $/MWh : 67 $/t
- dies, tools: 60 $/t
- other material: 34 $/t
- maintenance: 3 % of the equipment's value

  25 220 000 x 0,03 = 756,000 $/year

  756 600 : 11 500 = 66 $/t specific cost
- costs of wage type taking into account 580 employees and wage of 420 $/month : 254 $/t
- specific charge for current assets (in the case of good organization of labour, a 10 per cent interest on current assets amounting to $ 5,000,000) : 43 $/t
- specific costs for depreciation of an average rate of 6 % total annual depreciation:

  38 950 000 x 0,06 = 2 337,000 $/year

  therefrom, specific depreciation: 203 $/t.
- specific interest expenses on credits raised abroad for investment purposes (on imported machinery only, reduced by the inflation rate; a 4 % interest can be considered): 88 $/t.

Summing up the above specific costs, it turns out that primary costs of 1 ton product amount in average to 2398 $/t. Substracting it from the average selling price of 2517 $/t, a 119 $/t profit results that cannot be considered satisfactory since it does not permit even the raised credits to be refunded on schedule. Further difficulties can arise from the fact that due to lack of skill and appropriate market relations, a capacity exploitation of not more than 50 to 75 per cent can be envisaged for the first year of production.

A sure improvement of the situation can be expected due to the following:

- Along with an economical recovery, a revival of the demand for aluminium products and an increase in the phase price, i.e., the difference between the price of pigs and that of semi-finished goods, may be expected.
- The installed capacities should be exploited as fully as possible; therefore, a step-wise implementation of the project must be recommended, i.e., first one of the Variants with one press should be chosen and the installation of the second one and extension of other plants should be started after the first is fully operational.
- It should be examined whether another production programme could be realized more economically and profitably.

These considerations show that a complex overall survey must be carried out before a decision in respect of the project investment is taken. For such a survey and the decision relying upon it, an analysis of the local conditions and circumstances is indispensable. Target functions directing the activity cannot be set up unless the possibilities and aims of the country are profoundly known. The same holds for stating whether, in an initial period of time, transitory difficulties should and could be tackled with a view to create a new industry.

Anyway, it is highly advisable to have a feasibility study prepared after the decision in principle in respect of the establishment has been taken; this study should deal in detail with topics and questions as follows:

- market analysis and, relying on it, recommendations as regards the product mix to be manufactured and the marketing plan;
- survey of sources of raw material;
- appraisal of the required fixed and current assets, of the production costs and outline of expenditures based on the former;
- evaluation of sites which may be taken into account as suitable for establishment of the plant;
- calculation of labour requirement and methods of recruitment of manpower;
- a rational scheduling of implementation;
- financial resources of establishing, calculations of credit and interest amortization.

If the activities are properly organized and co-ordinated, a factory as described herein must be able to be commissioned not later than two years after the date of the final decision concerning its establishment. A bar chart showing the major steps of the project realization broken down by months is illustrated on Fig. 14.

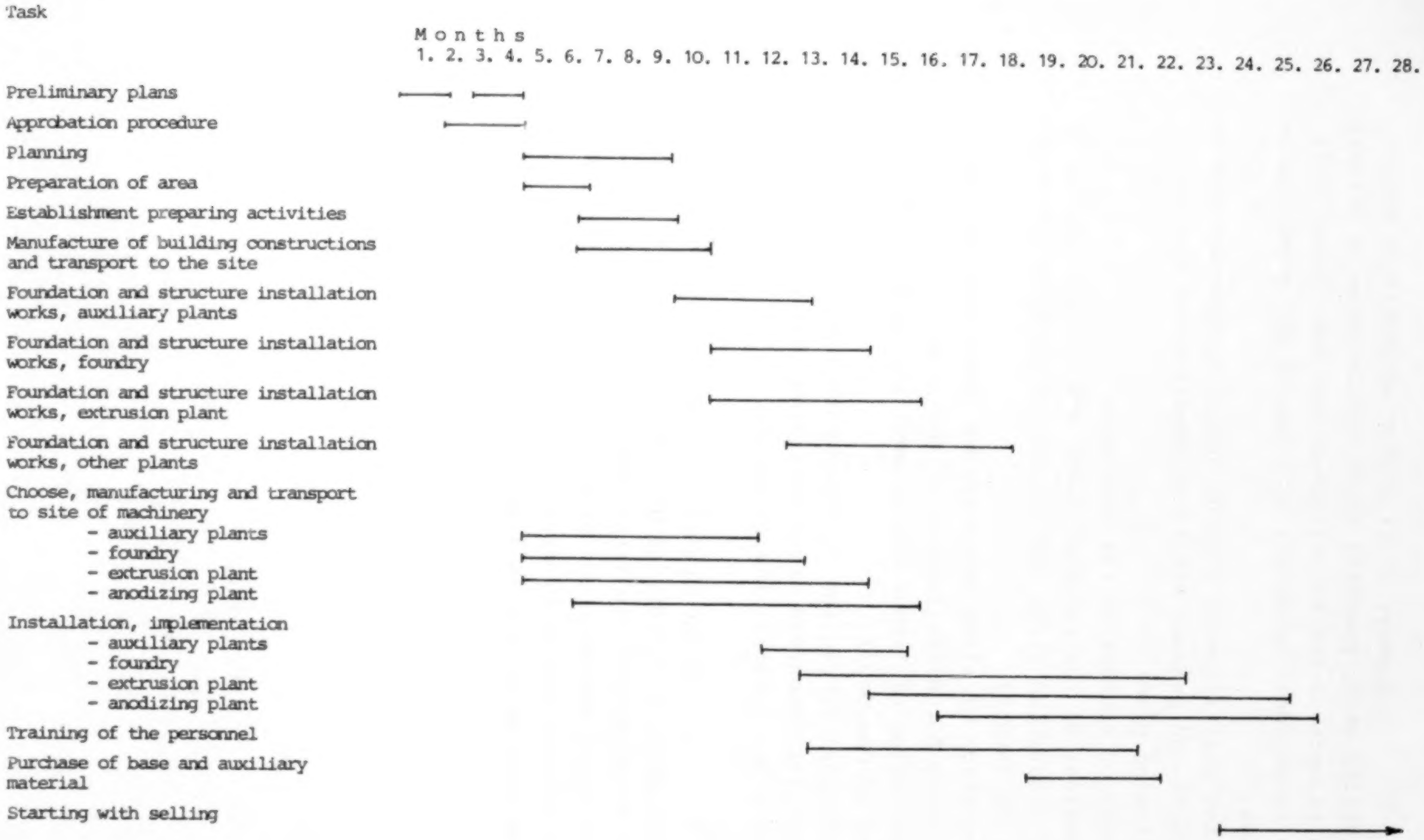

Fig. 14 - Bar chart for establishing a factory